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ANTARCTIC CLIMATE, CLOTHING AND ACCLIMATIZATION

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A. F. ROGERS and R. J. SUTHERLAND

Department of Physiology, University of Bristol, England.

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CONTENTS

List of Tables.

LIST OF ILLUSTRATIONS.

S U M M A R Y

(1) A detailed computer analysis was made of the clothing worn by the members of the Trans-Antarctic Expedition, and the relevant climatic data. The analysis covers a period of just over fourteen months and includes the 2,158 mile journey across Antarctica. The cold stress was severe.

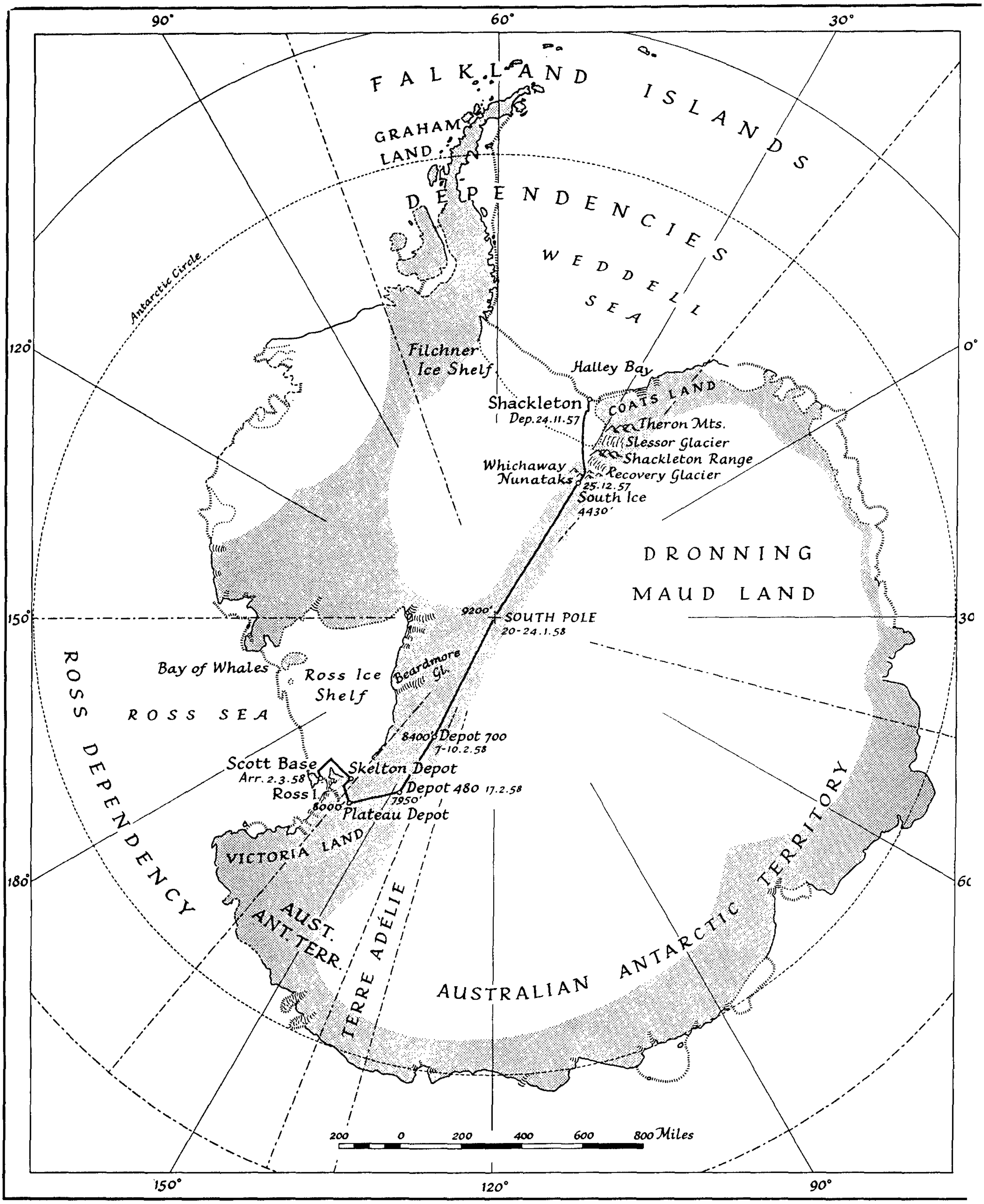
(2) No evidence of whole body acclimatization to cold in man could be found.

(3) The clothing worn was clearly shown to be more closely correlated with temperature than with windchill.

(4) The measured clo values of twentyeight different assemblies of Antarctic clothing were compared. A simple direct relationship between a weighted 'number of layers' count and the clo value of an assembly was shown to exist. This relationship is of immediate use in comparing the relative thermal insulation of two cold weather clothing assemblies.

(5) Other data, including weight fat thickness and sleep records, are discussed.

(6) The data presented are consistent with the suggestion that man creates and controls his own micro climate.



Royal Geographical Society

PLATE II (1)

Map of Antarctica showing route of the Trans-Antarctic Expedition from Shackleton Base on the Weddell Sea via South I[illegible] and the South Pole to Scott Base on Ross Island.

INTRODUCTION

Sir Ernest Shackleton set out in 1914 with the intention of crossing the Antarctic Continent from the Weddell Sea to the Ross Sea, but his ship, the Endurance, was crushed in the ice and the crossing was abandoned. The idea was revived in 1949 by Sir Vivian Fuchs, and the Commonwealth Trans-Antarctic Expedition became a reality. (Map - Plate II.1) An Advance Party set up a base named after Sir Ernest Shackleton on the floating Filchner Ice Shelf at Vahsel Bay at the southern extremity of the Weddell Sea and endured an extremely harsh winter living in a large packing case and tents. Next summer the Main Party arrived.

During the period covered by this report, the Trans-Antarctic Expedition had sixteen men in the field, forming the 'Main Party'. Four of these men had also spent the previous winter at Shackleton Base as members of the 'Advance Party' and stayed on, being joined by twelve men brought in by the ship Magga Dan on January 13th 1957. (This ship took home returning members of the Advance Party.)

The Main Party finished the base hut and set up an inland base called 'South Ice' by air, approximately 300 miles inland from Shackleton at an altitude of 1350 metres, on 4th February 1957. Three men spent the 1957 winter at South Ice, one of them having been a member of the Advance Party. Of the thirteen men wintering at Shackleton, three had also spent the previous winter there as members of the Advance Party. Four of the men at Shackleton that winter were members of the R.A.F.

At the end of the winter, a reconnaissance party explored the ground route from Shackleton to South Ice, while other parties mapped various mountain ranges and made geological surveys. This Main Party of twelve men then made the first ground crossing of the continent in the summer of 1957-58, using Sno-Cats and Weasels, while the four R.A.F. men made the first single engine flight across the Antarctic Continent.

The Crossing Party left Shackleton Base on November 24th 1957, arrived at South Ice on December 23rd, left on December 25th and arrived at the South Pole on January 19th 1958. They left the American Scott-Amundsen South Pole Base on January 24th and completed their journey at Scott Base on March 2nd, 1958 and sailed for New Zealand three hectic days later. The full story of the expedition is given by Fuchs and Hillary. (1958)

The expedition and the crossing in particular was timed to coincide with the International Geophysical Year.(I.G.Y.) This was the third I.G.Y. The first International Polar Year concentrated on Arctic work in 1882 to 1883, and the second International Year in 1932 to 1933 on radio communication. The third I.G.Y. from July 1957 to December 1958, a time of peak sunspot ctivity, involved 5,000 scientists in 40 countries in a vast collection of earth science data, and concentrated on the Polar Regions, the Equatorial Belt, and stations along chosen lines of longitude between North and South Polar Regions. There were 46 I.G.Y. stations in Antarctica involving a dozen nations and hundreds of scientists.

(1) DATA COLLECTED DURING THE TRANS-ANTARCTIC EXPEDITION

A 'sleep card' was issued to each man each week, (Figure V (1)) and this gave records of all the clothing worn each day, the outdoor work, and had spaces for weight and fat thickness measurements and other data such as weather, dental treatment, photograph, illness or injury or other items of special interest together with a day by day sleep and work diary. The back of the card was blank and many members wrote long and useful comments and explanations of their activity, clothing or camping conditions on the backs of the cards. Despite the ardous conditions and extremely long hours, the cards were filled in regularly and faithfully by all the men. Only at the end of the crossing is one set of cards really short of data. An immense 'thank you' is due to all the members for filling in these cards, often wearing several layers of gloves in very trying conditions.

Everyone helped with the meteorological records, but they were the entire responsibility of one man, Hannes La Grange, and his patient work was of a very high order. Detailed weather recordings were made at synoptic times (mostly three hourly) at both bases and by all parties in the field.

In addition, medical and dental records were kept and physiological investigations included measurements of energy expenditure under various conditions including travel. At base an energy balance was carried out on one man for one week. These results will be published elsewhere.

The data analysed here is in short the clothing worn by a dozen men for fifteen months and the weather every three hours or so for the same time, during the occupation of bases in Antarctica and a journey across the continent lasting ninety nine days.

Samples of new and used clothing were brought back to the U.K. and have been subjected to detailed examination, and the clo values for twenty four assemblies were measured in the U.S.A. and for four assemblies in the U.K.

(2) E.O.A.R. GRANT

Strenous efforts were made to collate and assess the immense mass of figures resulting from the physiological programme Three statisticians in turn, after expressing intense interest, retreated from the project after a year or so in each case, as it proved impossible to handle the material as a spare time project. It was not, in fact, until 1968 that the possibility of a grant for a full time mathematician/statistician arose.

Following a lecture on the expedition, given by Dr.A.F.Rogers in Washington in 1968, during the International Physiological Congress, a discussion of the limited analysis made up till then of the mass of data available resulted in a suggestion that an application for funds should be made to the Office of Aerospace Research, United States Air Force, and this was successful.

Mrs.R.J.Sutherland, an Honours Mathematics Graduate, was appointed on November 3rd, 1969, and was responsible for the computer program and the statistical analyses. Mrs. E.Fountaine gave secretarial help from October 20th,1969, until Miss V.Thornton took over on March 19th, 1970. Miss Thornton also undertook the formidable task of coding the data. The entire mass of computer card data is stored in archives. The group broke up on April 8th, 1971.

The delay in starting the analysis was a blessing in disguise since until comparatively recently there was no computer available in the region that was large enough to handle the mass of data which amounted to approximately a million 'bits'.

III PREVIOUS WORK

It is generally agreed that man evolved as a relatively hairless animal (i.e. one without fur or wool protection) in a tropical or sub-tropical environment, and bony remains indistinguishable from modern Homo Sapiens can be found from the mid Pleistocene onwards. It is extremely likely that the necessity to follow the animals that he fed on, led man to enter colder regions. This in turn led to the use of clothing for protection and there is good evidence that man wore tailored skin clothing 20,000 years ago. (Woodbury 1968)

When modern man, accustomed to living in a temperate zone, returns to a tropical climate, then, quite apart from shedding some of his clothing, he readily adapts to the hot environment, and this adaptation is easily demonstrated, well marked, and undisputed. On the other hand, attempts to demonstrate adaptation to cold have been generally unsuccessful. Certainly there are local changes, especially in the hands, and also in the face and feet, but no 'general adaptation of the whole body' has been shown, and there are no profound and well marked physiological changes such as those accompanying increased ability to deal with heat stress.

The best demonstrated local changes are in the hands. Mackworth (1953) at Fort Churchill, showed by means of a two point discrimination test that indoor and outdoor workers differed in their ability to distinguish a gap after a standardised exposure of the hands to a cold air stream. Subjects exposing their hands to cold air for two hours a day and tested by the standardised cold air stream and two point discrimination test, at first showed loss of discrimination after cold air chilling, but after two weeks their ability began to improve. This type of test was used in the Antarctic by Massey (1959) who showed newcomers took seven weeks for their fingers to show a resistance to chilling comparable with that of men resident in Antarctica for the previous year.

Local acclimatization of the hands to cold in fish handlers is well marked and has been studied in detail by Le Blanc, Hildes and Heroux (1960) and by Nelms and Soper (1962) who showed it to be due to cold vasodilation.

Evidence of acclimatization of the whole body to cold is scanty, although there are remarkable examples such as the Australian aborigines who sleep almost naked in the open under conditions where the air temperature often falls below freezing point. (Goldby, Hicks, O'Connor & Sinclair 1938; Scholander, Hammel, Hart, Le Messurier & Steen 1958) The Yahgan, now almost extinct, living in Tierra del Fuego at an annual mean temperature of 6°C, were described by Darwin (1832) as wearing practically no clothes.

The Eskimo, inhabiting the cold Arctic regions, might be expected to show acclimatization to cold. In fact, he appears to create his own microclimate around his body by the clever use of very well designed clothing, and to survive in an extremely harsh environment by the skilled use of specialised techniques, derived empirically over a very long period of time.

Various studies have been undertaken of the members of polar expeditions, to look for evidence of acclimatization to cold. If distinct physiological changes could be shown to occur as a result of moving from a temperate to a cold environment, and to regress on return to the former climate, then a firm case for acclimatization to cold could be made. This would also apply if changes could be shown in response to a move from a cold climate to even harsher conditions. (for example when an expedition leaves a base camp and then returns) It is to be expected that members of polar expeditions are subjected to considerable selection, including self selection, and it is doubtful that those who dislike or suffer cold conditions poorly would even apply for inclusion. It is likely, therefore, that members of polar expeditions are already aware that they can tolerate or even like the conditions, and it is of course common for major expeditions to have a considerable proportion of very well experienced members, thoroughly familiar with the conditions

and choosing to extend their experiences. It might seem, therefore, that adaptation to cold might be found in such a population, if anywhere at all.

On the other hand, Macpherson (1958) has argued convincingly that man, as an animal devoid of clothes, fire and shelter, is best suited to the warm equable environment of a tropical forest, and Martin (1930) supports this view. Man's remarkable capacity for heat loss by cutaneous vasodilation and sweating, fit him for activity in this environment. His critical temperature is 25°C to 27°C, and he normally requires a high nocturnal temperature for sleep. He is well equipped for heat loss and not for heat conservation, and has very scanty body hair. He can adapt well to high environmental temperatures but his minimal environmental stress is in tropical conditions. Temperate conditions represent the lower boundary of adaptation to lower temperatures, and Macpherson argues that it is fruitless to attempt to demonstrate profound physiological changes in temperate man on exposure to severe cold, as he has already adapted as far as he is able. Only by creating his own micro-climate within his clothing can man survive polar conditions. By wearing a knitted wire vest and pants and using them as a resistance thermometer,(Wolff 1958) the micro-climate has been measured by Norman (1962) and found to average 32°C to 33°C, indoors and out, throughout the Antarctic year. Similar results were obtained by Cumming,(1961) and the results of Hampton (unpublished) are quoted by Edholm and Lewis (1964) in a most useful survey.

Adam, (1958) using the wire vest method, measured sub-clothing temperatures in members of the Trans-Antarctic Expedition and others who had been in Antarctica for fifteen months, and could find no significant difference between them and the new arrivals.

The Advance Party of the Trans-Antarctic Expedition were based at Shackleton, where the weather was very cold, dry and windy. They were subjected to unusually harsh conditions (Goldsmith 1959) and weekly clothing records were used to show

acclimatization to cold. (Goldsmith 1960) As pointed out by Edholm and Lewis (1964) the records show that the extremities may adapt, but there is no absolute support for general adaptation, even under these severe conditions.

Using a similar count of the number of garments with a comfort index and wind chill calculations, Palmai (1962) found changes in clothing, indicating adaptation, but no changes in the protection of the extremities. However, the conditions of Palmai's work were almost temperate, or at any rate sub-Antarctic, rather than Antarctic; the temperature range was +25°F to +50°F, and the weather was cold, wet and windy. Lugg (1965) also used a subjective 'comfort index' together with a 'number of layers' count and a wind chill index at Davis Base. As his averaged results for nine subjects showed only a slight decrease in clothing worn after mid winter with an increase in the subjective comfort vote, he was only justified, as he says, in suggesting that acclimatization had occurred.

General metabolic studies have been made by many workers looking for evidence of acclimatization to cold, and both Edholm and Lewis (1964) and Hammel (1964) have surveyed the work from slightly different points of view. Basal metabolic rates (B.M.R.) are generally agreed to be lower by a few per cent in persons living in a warm climate. Cold climate studies have not yielded any clear cut conclusions about the effect of a cold climate of the B.M.R., although here it must be remembered that the actual measurement of the B.M.R. is made in the absence of a cold stress.

Measurements of oxygen consumption and skin and rectal temperature during cold stress of varying duration and degree have been made by many workers, (Hammel 1964) and a general survey by these methods of all ethnic groups seems desirable, and indeed a start has been made. Hammel (1964) reviews the studies on general metabolic acclimatization including his own on the Alacaluf Indians of Tierra del Fuego. A useful

review is given by Budd (1964) of the whole problem in relation to his own metabolic studies in Antarctica, which showed an increased ability in four Caucasians to maintain rectal temperature during cold stress. This was attributed to general acclimatization to cold.

Edholm (1960) argued that no absolutely clear cut evidence of acclimatization of man to cold existed, but Scholander (1960) pointed out that the ability to rest and sleep was essential to survival, and this could certainly be acquired in a cold environment. A number of descriptions of this ability in primitive communities have already been quoted, and several detailed studies have now been made in Caucasians. Andersen (1964) reviewed the literature and reported controlled experiments on young Norwegians very similar to those of Scholander (1958) except for lower skin temperature in the feet. Scholander's (1958) subjects also had insufficient bedding while camping in the Norwegian mountains, yet developed the ability to sleep with a warm surface and a heat production raised 50% above the normal by frequent shivering. Control subjects slept poorly, shivered, did not mobilize as much heat and had colder feet and body surface. Cold stress has varied in most experiments and this may account for some of the discrepancies and conflicting results quite apart from the difficulty of agreeing on definitions.

The B.M.R. of animals is closely related to size rather than any other conditions or character, and mouse, man and elephant all lie on the same curve. Some species deviate a little and all change slowly with age.

The numerous measurements of B.M.R. in man in a variety of cold conditions show no great changes from normal, and it is reasonable to conclude that the B.M.R. was fixed with regard to size in the long course of evolution of warm blooded mammals. (Irving 1960) In cold conditions animals react in different ways. Most of the large Arctic animals are so well insulated that they can remain still on snow or ice without metabolic

compensations. On the other hand, small birds in the cold treble their heat production for long periods by shivering, even during sleep. During food seeking their muscle energy expenditure is enough to keep them warm. While shivering is the most important method of heat production in normal animals in the cold, non-shivering thermogenesis is well proven in the rat. (Cottle & Carlson 1956; Carlson 1960)

In general, it appears therefore that man, a tropical animal by origin, already shows some adaptation to cold stress in his life in a temperate climate, and can develop a little more adaptation when subjected to more severe cold stress - but only a little more. There is no profound overall body change and readily observed adaptation as observed in a hot climate. Only by the skilful use of clothing can man survive in a polar climate.

The members of the main party of the Trans-Antarctic Expedition lived at Shackleton Base in Antarctica for a winter, then drove across the continent in Sno-Cats and were exposed to considerable cold stress. Since detailed meteorological and clothing records were kept, the data was suitable for a close search for evidence of acclimatization of man to cold. The analysis of this data is presented in this publication.

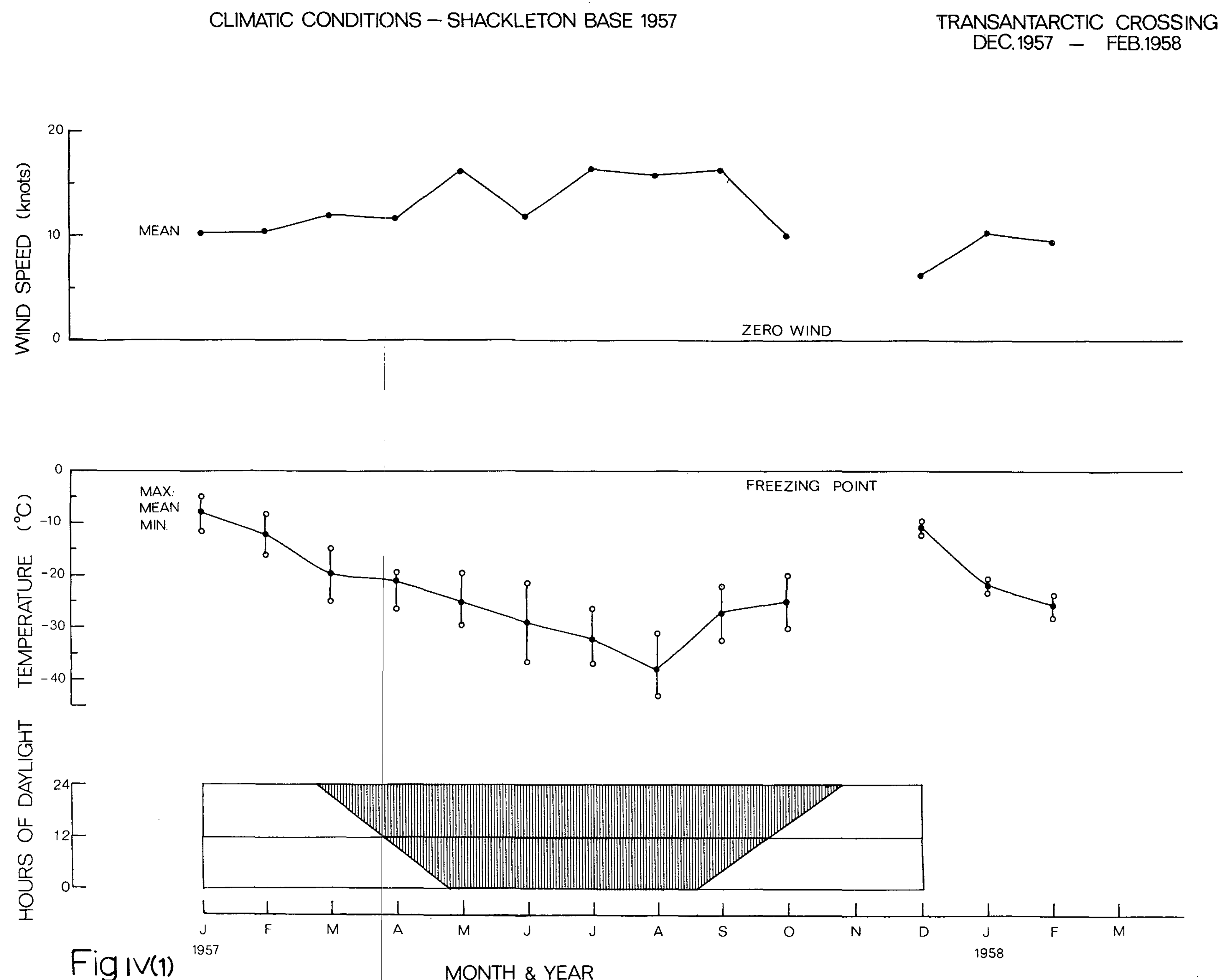

CLIMATIC CONDITIONS – SHACKLETON BASE 1957
TRANSANTARCTIC CROSSING
DEC.1957 – FEB.1958
WIND SPEED (knots)
20
10
0
MEAN
ZERO WIND
TEMPERATURE (°C)
0
-10
-20
-30
-40
MAX.
MEAN
MIN.
FREEZING POINT
HOURS OF DAYLIGHT
24
12
0
J F M A M J J A S O N D J F M
1957
1958
MONTH & YEAR

Fig IV(1)

IV THE TRANS-ANTARCTIC EXPEDITION

An outline of the story has been given already in the introduction, and full details are given by Fuchs and Hillary. (1958) Further technical details are given in the Trans-Antarctic Expedition Scientific Reports, those of particular relevance being No. 13 Meteorology by J.J. La Grange and No. 15 Survey by K. V. Blaiklock, D. G. Stratton and J. H. Miller 1966. A brief resumé of details pertinent to this analysis of clothing and climatic conditions is given in this section.

(1) POSITION OF SHACKLETON AND SOUTH ICE BASES

Shackleton Base

This was established at Vahsel Bay at the foot of the Weddell Sea at 77°59 South and 39°09 West on the floating Filchner Ice Shelf about a mile inland from the ice front. The base rose and fell with the tide but a mean height of 58m (190ft.) was accepted for reference. The ice shelf was 400m (1300ft.) in thickness and the depth of the sea 900m (500 fathoms) Shackleton was occupied from 30th January 1956 until 27th December 1957.

South Ice Base

The inland base was established at 81°56′ South and 28°51′ West, 25 miles south of the Whichaway Nunataks and 297 miles shouth of Shackleton at an altitude of 1,350m (4,430 ft.). South Ice was occupied from 4th February 1957 until 6th January 1958.

(2) ENVIRONMENTAL CONDITIONS

Antarctic weather is typically very cold and windy. The lowest temperature recorded at Shackleton in 1957 was -55.1°C on 20th August and the highest temperature +2.8°C on 13th December 1956. The lowest temperature recorded at South Ice during 1957 was -57.3°C on 29th July and the highest -8.2°C on 13th December. The average monthly temperatures at South Ice were always lower than the average monthly temperatures at Shackleton.

CLIMATIC CONDITIONS — SOUTHICE 1957

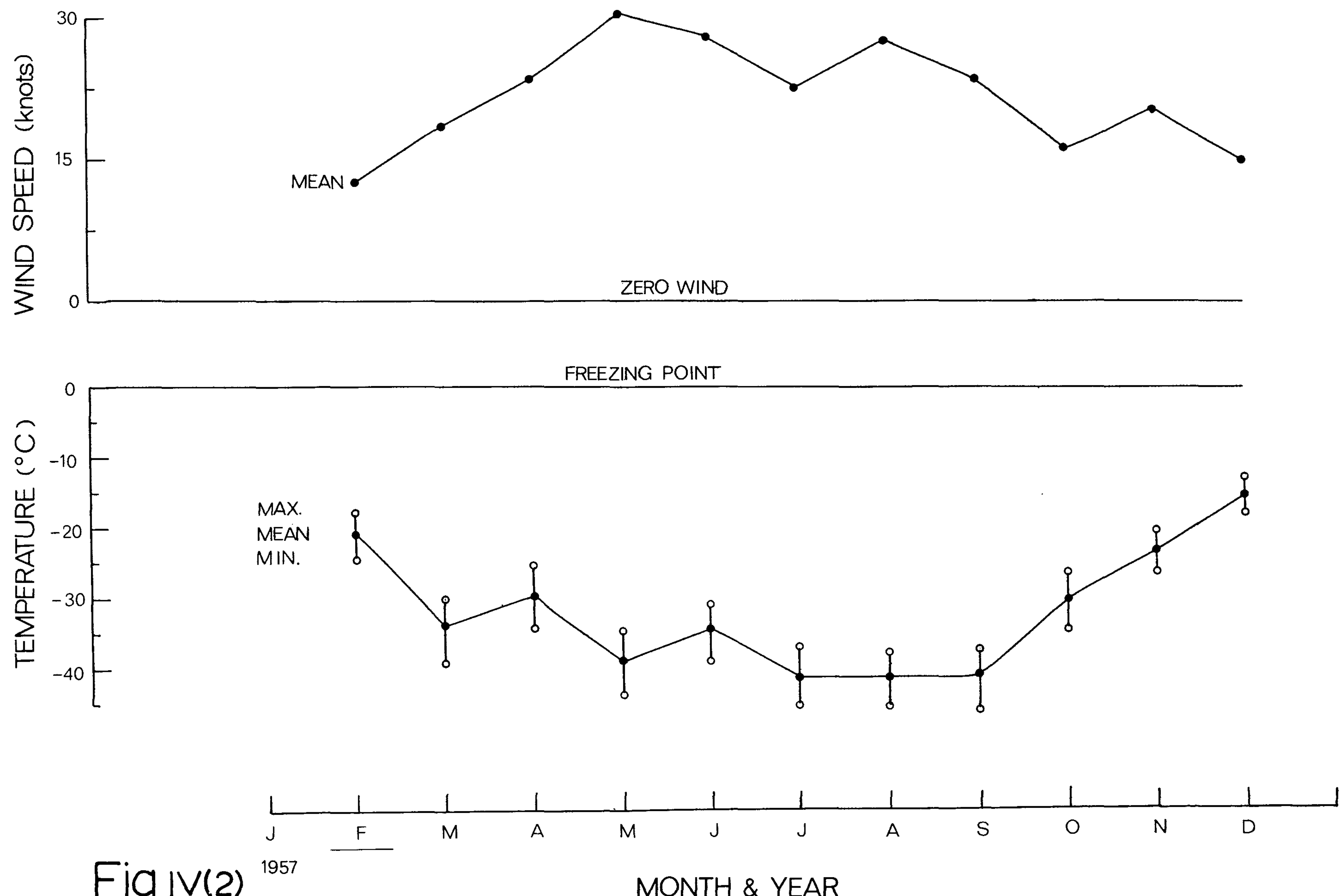
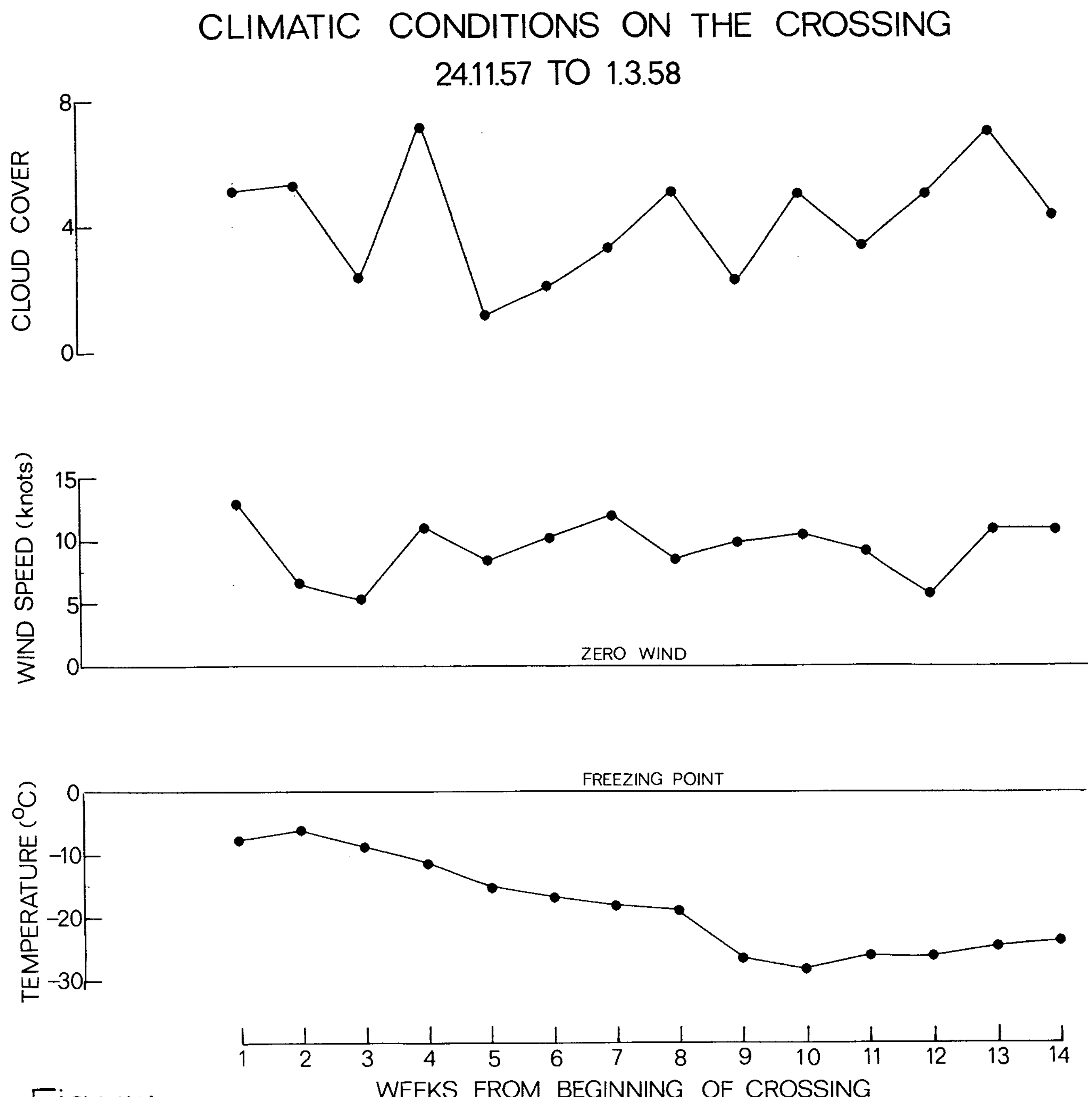


Fig IV(2)

Three hourly meteorological observations were made at Shackleton, and six hourly observations were made at South Ice during 1957. The wind data refers to a height of 10m above the surface at Shackleton and to a height of 8m at South Ice. There are no satisfactory radiation results for Shackleton in 1957. For four months during the winter(May, June, July and August) the sun did not rise above the horizon and for four months during the summer (November, December, January and February) the sun did not set. During the light months the sun was often obscured by cloud.

The humidity factor has not been taken into account because this has little effect on the comfort of men in the cold. (Edholm & Lewis 1964)

For the period of the crossing, meteorological observations were made at intervals of three hours, except during the periods for sleep. The minimum temperature recorded was -35.9°C and the maximum temperature recorded was -13.1°C. The conditions on the crossing were more severe than the conditions at base during the same period the year before. On the crossing, the only protection the men had was provided by the vehicles and the tents at night. They were therefore more continuously exposed than they had been at base. If acclimatization to cold occurred, it should become most apparent during this period. The crossing data was therefore examined first (and in greater detail) to see what evidence of acclimatization could be found. The analyses are considered here however in the chronological order in which the events occurred i.e. base data first, followed by the crossing data.



CLIMATIC CONDITIONS ON THE CROSSING
24.11.57 TO 1.3.58
CLOUD COVER
8
4
0
WIND SPEED (knots)
15
10
5
0
ZERO WIND
TEMPERATURE (°C)
0
-10
-20
-30
FREEZING POINT
1
2
3
4
5
6
7
8
9
10
11
12
13
14
WEEKS FROM BEGINNING OF CROSSING

Fig IV(3)

(3) PERSONNEL INVOLVED

A list of the names of those members of the Trans-Antarctic Expedition referred to in this survey is given in Table IV (1). This survey does not cover the activities of the Advance Party, (Goldsmith 1959) nor does it cover the Ross Sea Party. (Fuchs & Hillary 1958) The table gives the occupations and the subject number by which the individual is referred to in the rest of this survey. Subjects 1, 2, 3, 4 and 13 were also members of the Advance Party, and subjects 13, 14, 15 and 16 were members of the Royal Air Force contingent and flew across the Antarctic Continent while the other subjects, numbers 1 to 12 made the crossing on the ground in vehicles.

Table IV (2) gives the age, average fat thickness, average weight, the height and the surface area of each subject.

Surface area is given by the Du Bois-Meek formula

$$M^2 = W^{0.425} \times H^{0.725} \times 71.84$$

and is commonly read from a nomogram.

(W = nude weight in kg, H = height in cm surface area in square meters)

1956 - 1958 Trans-Polar Party	Subject No. Used in Survey for Identification
* Dr. V. E. Fuchs, Expedition Leader, Geologist.	7
D. G. Stratton, Deputy Leader, Surveyor.	6
K. V. Blaiklock, Surveyor	4
D. L. Pratt, Engineer.	8
Sergeant Major D. E. L. Homard, REME, Engineer.	3
R. A. Lenton, Carpenter and Radio Operator.	2
J. J. La Grange, Meteorologist (South Africa.)	1
. G. D. Pratt, Geophysicist..	5
Dr. A. F. Rogers, Medical Officer and Physiologist.	10
Dr. H. Lister, Glaciologist.	11
Dr. P. J. Stephenson, Geologist (Australia)	9
W. G. Lowe, Photographer (New Zealand)	12
Royal Air Force Contingent	
Squandron Leader J. H. Lewis, Senior Pilot	16
Flight Lieutmnant G. M. Haslop, Second Pilot (New Zealand)	15
Flight Sergeant P. Weston, Aircraft Mechanic.	14
Sergeant E. (Taffy) Williams, Radio Operator.	13

* Now Sir Vivian Fuchs.

Table IV (1) Membership of the Trans-Antarctic Expedition

Subject No.	*	Age at South Pole (Jan.1958)	Average Fat Thickness Nov.56-Feb.58 (m.m.)	Average Weight Nov.56-Feb.58 (K.g.)	Height (c.m.)	Surface Area (m^2)
1		30	18.41	90.5	184.2	2.14
2	F	34	17.9	80.2	172.1	1.93
3	A	37	5.57	66.7	171.7	1.79
4	F	30	6.94	67.5	179.1	1.85
5		30	12.44	85.4	186.6	2.11
6	F	30	10.18	74.9	182.9	1.96
7	AF	49	11.4	81.1	180.3	1.99
8		38	11.85	87.6	190.5	2.16
9		27	12.57	77.8	172.7	1.91
10	A	40	14.33	75.4	177.8	1.93
11	A	34	10.45	75.1	175.3	1.91
12	E	34	12.17	78.8	187.3	2.05
13		38	16.6	76.8	172.7	1.9
14	F	36	14.6	90.9	182.3	2.13
15		35	14.5	75.5	176.5	1.92
16	F	35	20.4	92.3	182.3	2.14

* = Previous experience of cold climate.

A = Experience in the Arctic (e.g. British North Greenland Expedition)

F = Experience in the Antarctic (e.g. as a member of the Falkland Islands Dependencies Survey)

E = Member of the Everest Expedition

Table IV (2) Characteristics of Subjects.

PLATE IV (1)
Icing-up of beard and moustache and accumulation of drift snow in the fur trimming of anorak hood. Winter 1957.

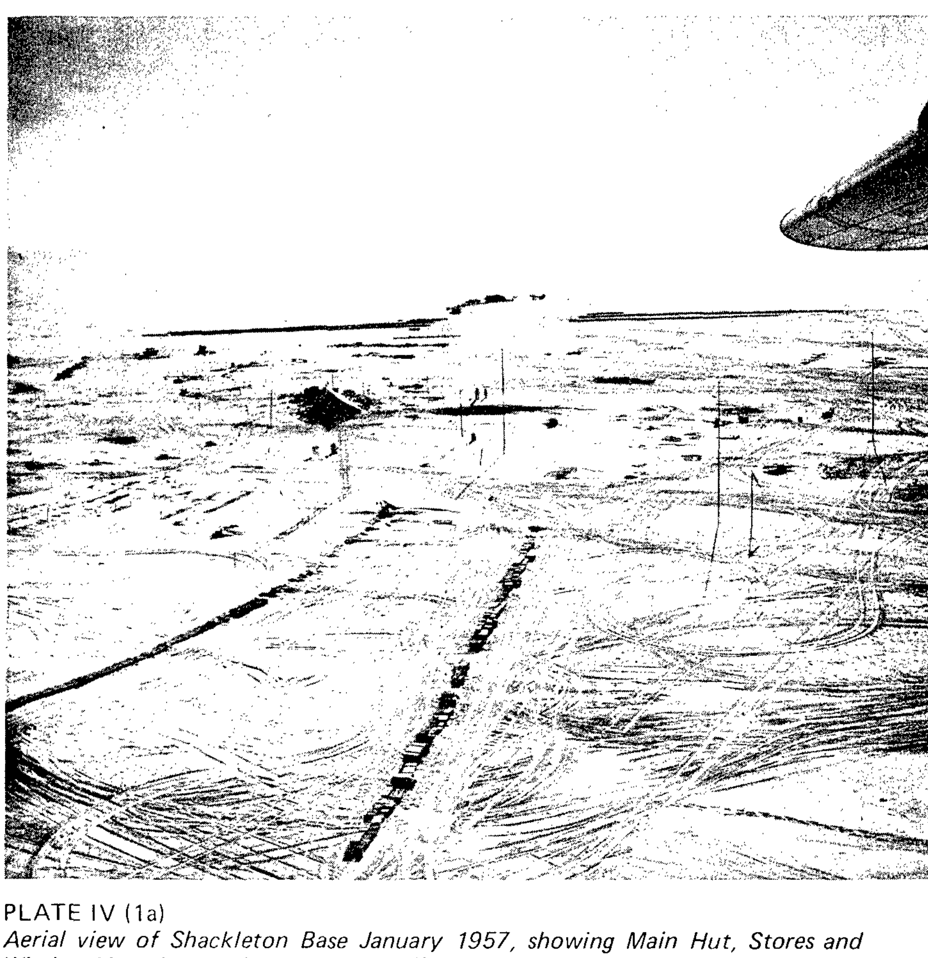


PLATE IV (1a)
Aerial view of Shackleton Base January 1957, showing Main Hut, Stores and Wireless Mast. In the distance are long lines of fuel drums.

(4) LIFE AT BASE

The extreme conditions in which the Advance Party had been living ended with the arrival of the Main Party and from the end of January 1957 onwards when the Base Hut was completed, life at Shackleton was comparable with that at any other medium sized Antarctic base, although the climatic conditions were rather more severe. A strict 24 hour routine was observed and emphasised by the diesel generators which thundered all day from breakfast to lights out, no matter whether outside there was the continuous darkness of winter or the 24 hours daylight of the summer season. Breakfast was from 8-9 a.m.; coffee 11-11.15 a.m.; lunch 1-2 p.m.; tea 4-4.30 p.m. and dinner from 7-8 p.m. Usually everybody worked all day until dinner and many relaxed over books or other occupations after dinner, but there were always a few working right up to lights out at about 11.30 p.m., at which time five or six people often had a hot drink and a quiet chat in the kitchen.

The hut was large and by Antarctic standards comfortable. Heating was by solid fuel stoves burning Phurnacite, and an Aga cooker gave the cook good scope for culinary skill. The air temperature at 2m averaged 13.5°C over ten months occupation. In the rafters at the apex of the hut clothing could be aired at 20+°C, but floor temperature was about freezing point. There was often ice on the floor and a blow lamp was always used when the floor was being scrubbed. The hut was buried by snow and only the apex of the roof could be seen from a distance. Entry was by steps down to a tunnel leading to a door and there was always difficulty keeping this clear of drift snow. One man in turn was cook for a week and had two 'Gash Men' to wash up, stoke fires and saw up snow blocks for the water supply tank. There was no fresh food of course (except occasional mustard and cress grown on trays in the loft). There was an adequate and varied supply of tinned food such as meat and butter, and dehydrated foods such as egg, milk and potato - a range of food typical of any Antarctic base. Fresh bread and cakes were baked several times a week. A capsule containing all known dietary supplements in suitable quantities was devised and each man took one a day throughout the expedition.

An energy balance was completed on one man over a period of seven days and nights, all food eaten being weighed, with a detailed analysis giving the calorie values (McCance and Widdowson 1960). Energy expenditure was measured with the Integrating Motor Pneumotachograph (Wolff & Fletcher 1954) and the results (already briefly referred to by Edholm 1960) will be published in detail elsewhere. The calorie

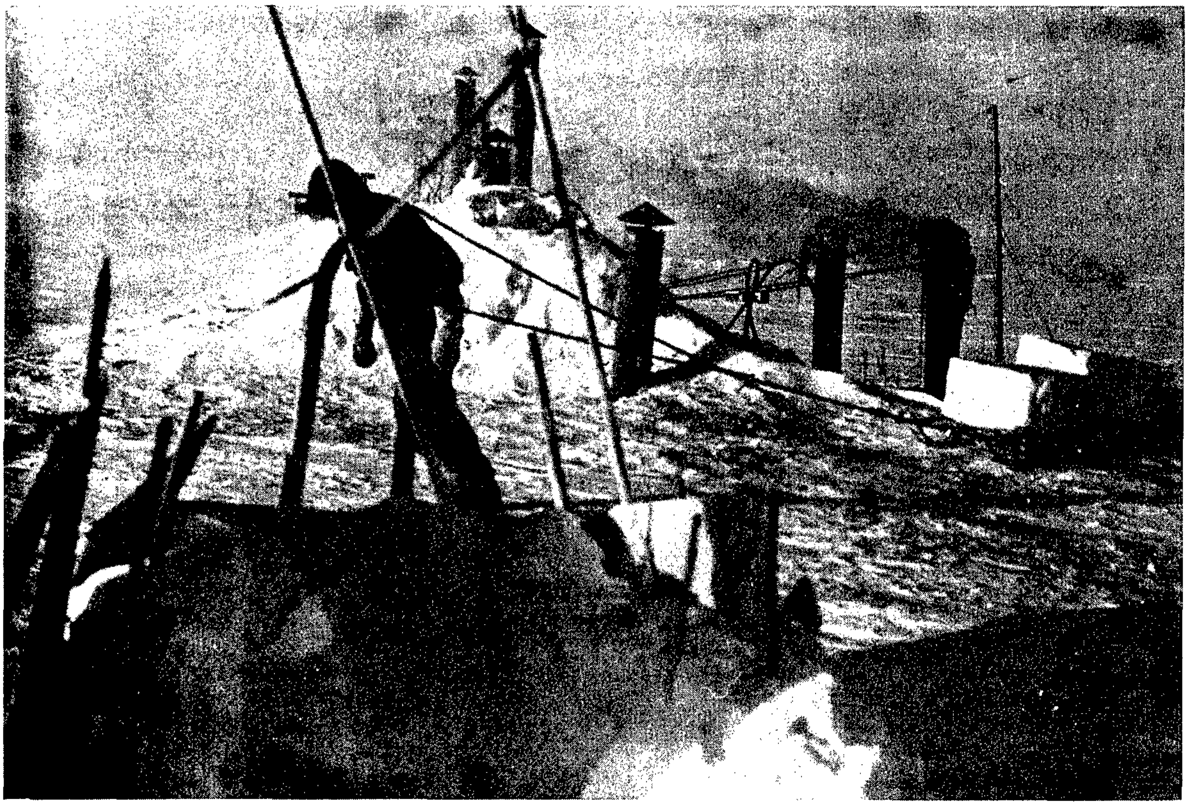


PLATE IV (2)
Shackleton Base – dragging in snow blocks for drinking water. Note drift scoop around trap door entrance to tunnel in foreground.

PLATE IV (2a)
Shackleton Base – entrance to Hut VIa steps to tunnel. Spring 1957. Seen from inside.

PLATE IV (3)
Ice formation on stubble beard in cold weather – condensation from breath. March 1957.

PLATE IV (4)
Lunch time break during crossing. January 1958. Note dogs resting.

intake averaged 4,100 Kcal a day, the total intake being 28,700 Kcal for the seven days. The subject (No.5) was large (height 186.6 c.m.; weight 84.8 Kg.; surface area $2.11m^2$) but the food intake for the other members was of the same order.

Normally every man except the cook spent part of each day outdoors. There were no special privileges, conditions were the same for everyone and everyone in turn shared the less pleasant chores such as scrubbing frozen floors and emptying latrine buckets. The only exception made, by common consent, was that one subject was excused cooking, not because he was unwilling to do his share but because the others were unwilling to share the results. He took a slightly larger proportion of other chores in consequence. Cooking was a real difficulty. It took highly skilled men away from the jobs they were trained to do and employed them in a task they had not trained for. It was inevitable however as the logistics of the crossing were so critical that no passengers could be carried. The vehicles could only drag food and fuel for the twelve men needed and planned for on the crossing,and each of these had his special task. There was no way out from Shackleton except across the continent by Sno-cat. (No relief ship was to come in). There could therefore be no cook at base since he would have been a non-productive passenger on the crossing. Despite this, wonders were achieved and a remarkably high standard of cooking maintained.

Morale was consistently high and there were none of the quarrels that have so commonly occurred in small groups of men isolated for long periods in difficult conditions. This was probably because the men were all volunteers and specialists with a specific task they wanted to do, and were competent in at least one other field of work as well. Everyone had been on other expeditions of various kinds and knew what to expect. The leader was a man of enormous experience and remarkable personality, but all important decisions (except in utmost emergency) were made after full discussion amongst the whole party and were joint decisions. Each man had absolute responsibility in his own field. The result was the extremely high morale already referred to, and a remarkable absence of internal strife.

TRANSANTARCTIC EXPEDITION. RATIONS ISSUED DURING THE CROSSING. 1 BOX/2 MEN/10 DAYS.

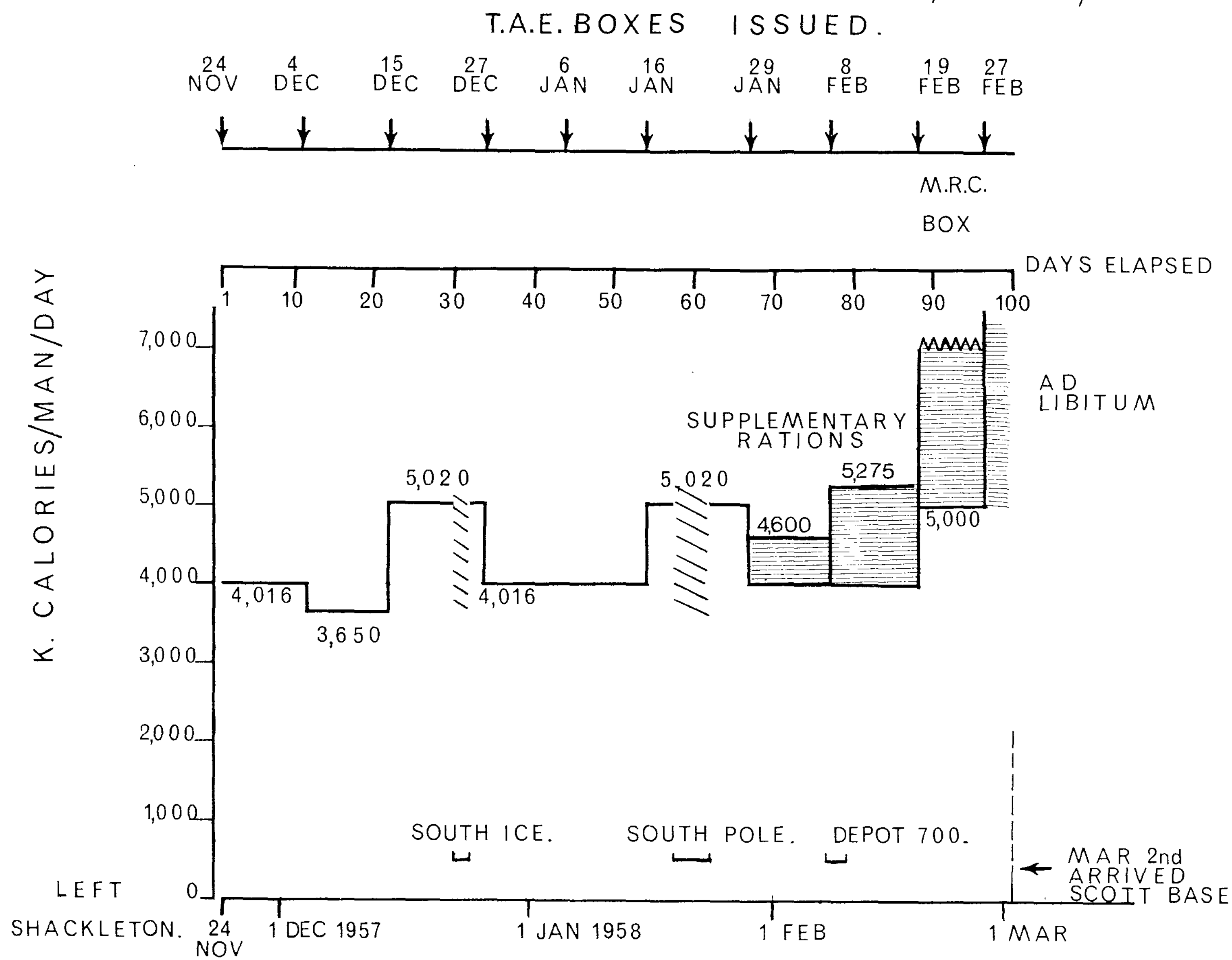


FIG IV(4)

TABLE IV(3)

CONTENTS OF T.A.E.SLEDGING BOX (2 MEN - 10 DAYS)

	Wt/oz.	Kcal/oz.	Total Kcal.	Kcal/man/day
1) Butter (6 tins ea. 1 lb.)	96	226	21,696	1,085
2) Pemmican (7 tins ea. 1 lb.)	112	167	18,704	935
3) Biscuits (24 pkts.of 6) 1 tin.	86.3	137.5	11,866	593
4) Sugar (4 pkts.ea.1 tin, 15½ oz.cube sugar)	62	112	6,944	347
5) Compressed Oats (1 tin, 3 lbs)	48	115	5,520	276
6) Milk Powder (2 tins ea. 1 lb)	32	150	4,800	240
7) Chocolate (5 bars, 2 oz.milk)	10	167	1,670	84
1 tin (5 bars, 2 oz.plain)	10	155	1,550	77
8) Kendall Mint cake (3 bars ea.6 oz)	18	111	1,998	100
9) Bacon (1 tin, 1 lb.sliced)	16	120(av.)	1,920	96
10) Pea Flour, 3 pkts.of 8 oz.	24	78	1,872	94
11) Cocoa (1 tin, 12 oz)	12	128	1,536	77
12) Potato (1 tin, 8 oz.dried powder)	8	103	824	41
13) Raisins or Dates (8 oz.pkt)	8	70	560	28
14) Sardines (1 tin, 4 oz)	4	84	336	17
15) Dried Onions (1 tin, 8 oz)	8	50(say)	400	20
16) Salt (1 oz)			Nil	
17) Marmite (2 oz) (or Curry Powder 2 oz)			Nil	
18) Tea (1 tin, 4 oz)			Nil	
			82,196	4,110

Total Kcal value for each box 82,196, giving 4,110 Kcal.per man per day.

T.A.E.Boxes issued Nov.24, Dec.4,15,27, Jan.6,16,29, Feb.8 and 27.

M.R.C.Box (2 men-10 days, 5,000 Kcal(day) issued 19 Feb.1958 (trial pack)

Supplementary Rations issued during crossing to each 2 man tent:-

25 Dec.'57. 1 lb.Dried apples, two 12 oz.tins Corned Beef, 1 lb.Jam.
27 Jan.'58. 3 lbs.Jam. 29 Jan.18 oz.Kendall Mint Cake, ½ lb.Dates, 1 Soup Powder (400Kcal), 12 oz.Luncheon meat, 1 lb.Milk Powder, 12 oz.Corned Beef.
5 Feb. 4 lb.Jam. 6 Feb. 4 oz.Cheese, 2 lbs.Steak(fresh). 8 Feb. 8 oz.Dates, 12 oz.Kendall Mint Cake, 5 Soup Powders, 12 oz.Luncheon Meat, 8 oz.Dried Egg, 4 oz.Sardines, 1 lb.Glucose Tablets, 1 lb.Jam, Bacon 5 oz, 22x2 oz. bars Chocolate, 4 oz.Cheese. 9 Feb.4 Eggs, 4 Oranges, 2 Apples. 12 Feb. 4-lb. Jam, 12 oz.Corned Beef, 16 oz.Dried Milk. 17 Feb.40 oz.Chocolate, 8 oz. Dried Egg, 12 oz.Corned Beef, 8 oz.Bacon, 16 oz.Dried Milk, 4 Soup Powders, 4 lbs. Sugar, 8 oz.Boiled Sweets. 23 Feb. 2 lbs.Steak, 4 Eggs, 8 oz.Luncheon Meat, 2 Cans Beer, 2 tins Peaches. 26 Feb. 1 Egg, 2 oz.Bacon.

PLATE IV (5)
Snow-cat trapped in mouth of crevasse.

PLATE IV (6)
Probing for crevasses. The man in the middle is standing on a wall of safe ice between two crevasses. The man on the left is testing the thickness of the crevasse lid on which he is standing.

(5) Sledging Routine

The sledging gear, the camping routine and the diet were the same for everyone, and were the result of many years experience and development by the members of the Falkland Islands Dependencies Survey,(F.I.D.S.) now the British Antarctic Survey (B.A.S.), and incorporated practical tips and methods from all sources available from the turn of the century onwards. Four of the members had already been on several previous Antarctic expeditions with F.I.D.S., and the entire expedition routine was firmly based on F.I.D.S.methods. In addition, five members had experience of other Antarctic or Arctic expeditions and one had been on the first successful Everest Expedition. Four had no previous polar experience but had experience with various other expeditions. All adapted well to the routine and worked harmoniously together. The group was notably free from internal strife.

The men camped in pairs using standard F.I.D.S. double walled pyramidal tents with a seven foot square base and seven feet high at the apex, supported by four very stout canes permanently fixed one in each corner so that the tent could be opened and shut quickly and easily like an umbrella. Internally the tent was six feet square at the base. Entry was by a tunnel or sleeve through each of the two walls and each sleeve could be closed separately or held open by tapes. There were also tapes at the apex inside, to hold pot hooks for duffles, inner gloves, socks, sweaters etc. to dry, and here a two inch rubber tube passed outwards horizontally through both layers of the tent wall as a ventilator.

A standard paraffin pressure stove (Primus) was used for melting ice and cooking the rations and this also warmed the tent and permitted the drying of clothes hung at the apex. The primus and cooking gear were kept in a standard F.I.D.S.sledging box and the rations for two men for ten days in a similar box.

The allowance of paraffin was two gallons for two men for fifteen days in the summer when indeed it could often be made to last for twenty days. In winter sledging, two gallons lasted from ten to twelve days. This allowance permitted the deliberate drying of clothes as well as cooking and is one of the most important changes in sledging routine in the last fifty years. Formerly, in the days of man-hauling of sledges, in order to keep the weight down, the absolute bare minimum of paraffin was carried with the result that clothes and sleeping bags were never dried out. As the outer layers of clothing are at temperatures well below freezing point, ice forms slowly but steadily within them from the freezing of insensible perspiration which of course is continually passing

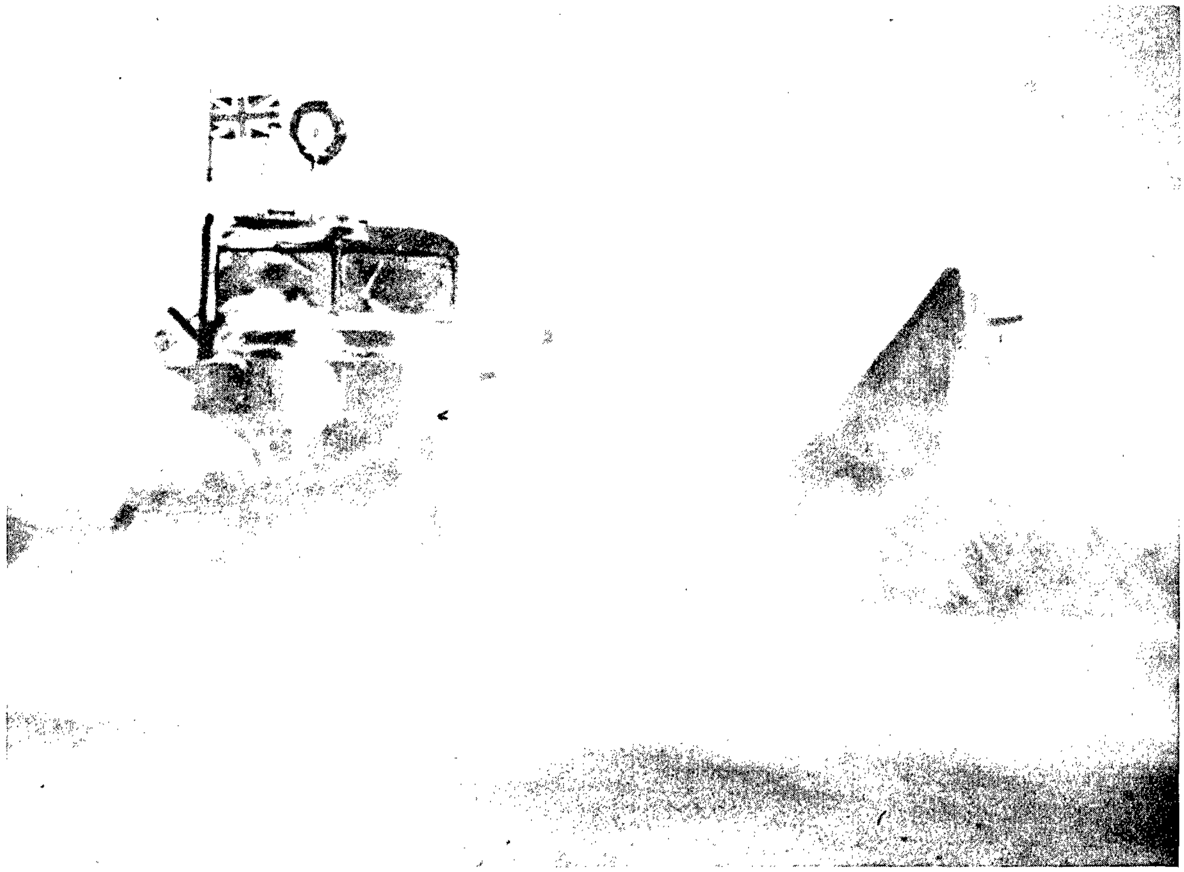


PLATE IV (7)
Snow-cat and tent. Typical camp during crossing in heavy drift.

PLATE IV (8)
Camp on the Skelton Glacier in high wind and drift snow.

out from the surface of the dry skin even when no sweating is taking place. (Burton & Edholm 1955, fig.17). Under these circumstances the gear got steadily heavier and disaster constantly threatened if there was the slightest shortage of fuel (see "Scotts Last Expedition" for example.) Nowadays as the result of a heavier starting load of fuel, the clothing in modern sledging techniques is always dried out at camp, thus preserving its heat insulation - and the load gets steadily less as fuel is consumed and no ice accumulates. The technique is safer and more comfortable.

The first act when camping was to choose the tent site and stamp the snow flat if it was soft. In the heavily crevassed areas especially at the beginning of the crossing it was sometimes difficult to find a safe area large enough for a vehicle and tent. Skis were worn continually outside the vehicles in these areas. The tent was pulled out of its bag, opened and the projecting ends of the four corner canes pushed a foot into the snow. Safety from the sometimes violent winds was given by loading snow blocks on the outer skirt that projected horizontally outwards all around the tent base. Several hundred pounds weight could be quickly and easily built up if needed. Guy ropes gave a little more room inside by pulling out each panel.

The "inside man" then entered receiving the ground sheet, two blankets, two sheep skins, two double layer sleeping bags, and the cooking and ration boxes from the outside man, who then attended to dogs, sledges or vehicles, and cut more snow blocks as required.

A brush was always used for cleaning snow off clothing and footwear on entering a tent lest it melt on the clothing. Inside the tent each man took off his headgear, windproof trousers and anorak, gloves, outer footwear and duffles and hung all these up to dry. A plume of steam could often then be seen issuing from the ventilator. Most people then sat in their double layer sleeping bag to cook, or eat or write, still wearing underwear, shirt, pullover, socks and trousers. This was partly for warmth and partly because the only other working position was kneeling which became quite painful after a time.

The evening meal was usually pemmican with potato powder or pea flour and some dried onion, sultanas, raisins, cheese or curry in a vain attempt to vary the flavour, and tea to drink. Breakfast was porridge with sugar, milk, butter and raisins and as much liquid as desired (usually tea), and the inside man then prepared a lunch of butter and biscuits with jam or marmite, and two pints of water or coffee or cocoa per person in a thermos. The edible portion of the T.A.E.

sledging ration (as distinct from the water, salt and roughage content - see Table IV(3).contained 17.6% protein, 36.4% fat and 46% carbohydrate. The daily intake per man from the basic sledging ration was protein 124g, fat 255g and carbohydrate 323g. Despite the high calorie value of the diet its bulk was low and some felt hungry while not eager to finish their pemmican. This passed off and the standard 2 man box issued every 10 days was supplemented by issues of jam, chocolate, tinned meat etc. as detailed in table IV(3), and by food provided for short periods at South Ice, and at the Amunsden-Scott Base at the South Pole, so that the daily intake rose from 4,110 Kcal given by the basic issue, to over 5,000 Kcal a day for much of the crossing journey. During the last two weeks a Medical Research Council experimental box giving 5,000 Kcal a day was issued and much extra food shared out. It is likely that this was all consumed since another T.A.E. box was issued three days before the journey ended (giving food ad libitum), and it was certainly consumed in at least one tent, giving the enormous total for a few days at any rate of 7,000 Kcal a day. Even so the four subjects for whom weight records are available during the crossing all lost some weight (see page IV.30).

Urination and defecation under normal conditions presented no problem, the shelter provided by any sledge or vehicle being adequate and the time involved short since the diet produced a fairly large soft easily passed stool. There was therefore no danger of frostbite under normal conditions. During blizzard conditions the absolute necessity of keeping the clothing dry and not allowing open garments to fill with drift snow necessitated defecation in the tent, usually immediately before striking camp. An empty food tin was used for urination during the night and the very greatest care taken not to spill urine on a sleeping bag. Husky dogs are eagerly coprophagous and a loose dog in a two day camp will scavenge widely and dig up faeces, presumably for bulk, as the fat content even on a sledging diet is normal (see Lewis H.E. and Masterton J.P.(1955), Lancet II 500;and Masterton J.P., Lewis H.E. and Widdowson E.M. (1957), Brit.Jl.Nutrit. II, 346-358)

An amusing phenomenon resulted from urination into recent snow, as the snow melted and the urine ran downwards and froze. The wind soon cut away the adjacent softer snow (as in the wind carving of sastrugi) leaving the hard ice behind like an upside down yellow fir tree. These were christened Uromites.

The critical logistics of the crossing limited personal gear to 30 lbs (13.6kg) which allowed for spare clothing, a 'housewife' for

sewing, tobacco, chocolate, one book and a camera.

Pitching camp and breaking camp each took about an hour. Particular care was always taken to close bags and boxes before passing them out of the tent since drift snow covered everything on the sledges and penetrated all openings.

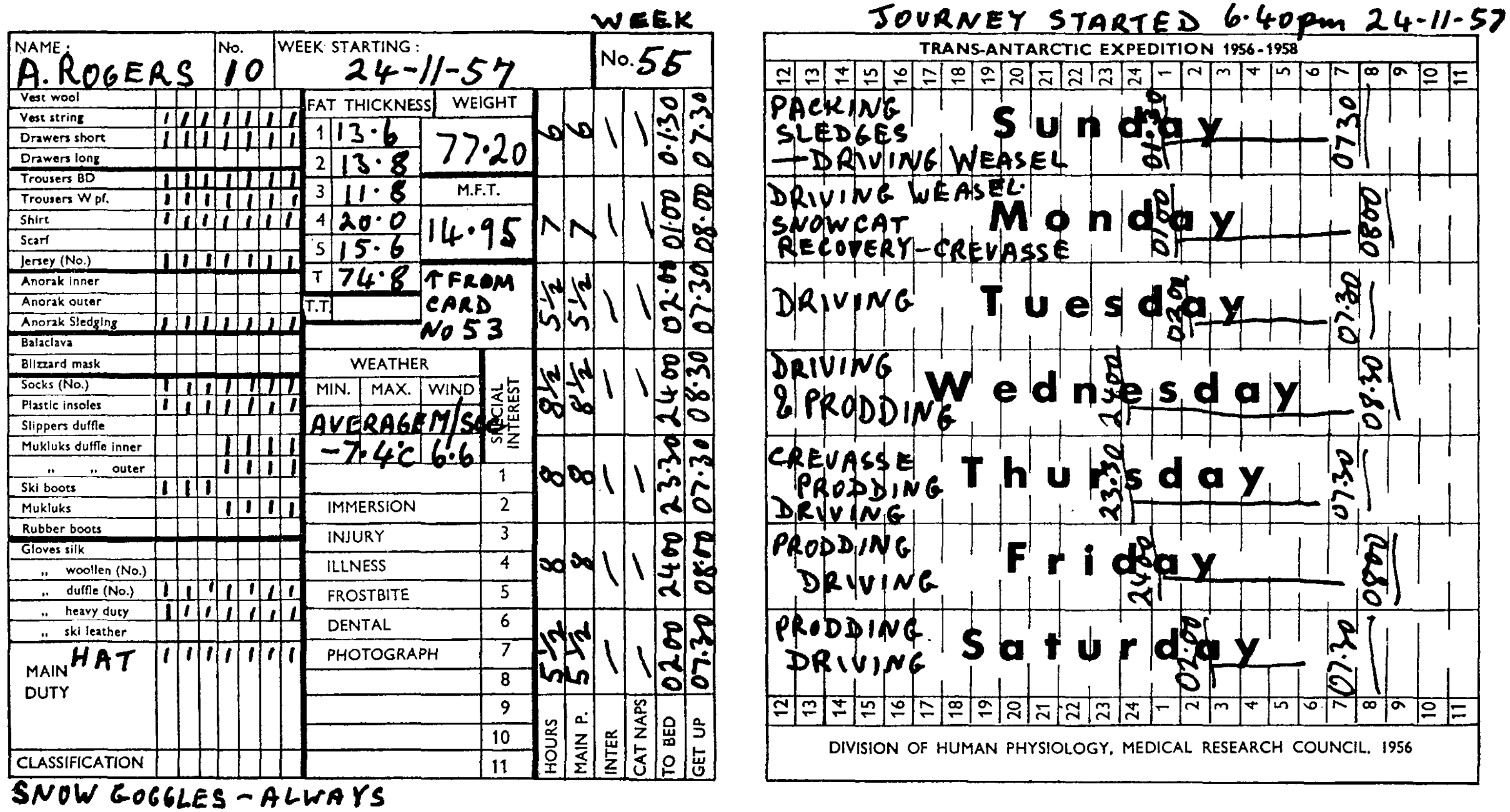
Owing to the long hours of driving, sleeping time became less during the journey, dropping at the end to 5 hours a night from an average of over 7 hours at base. Scientific work during the crossing had to be done during this period otherwise available for sleeping.

Temperatures in the tents rose from ambient to +40°C. at the apex within minutes of lighting the Primus. The air temperature at 1m measured over periods of 40 minutes on 14 occasions during metabolic measurements ranged from + 1°C to + 15°C and depended on whether the sleeve entry way was open or closed and on how long the Primus had been burning. The average was 5.1°C. The temperature fell rapidly as soon as the stove was out an d was usually between - 10°C and - 20° C on waking. Ice collected in the blanket (of synthetic material) placed under the sleeping bag during the night and a lesser amount collected in the sheep-skin, and this was removed by shaking each day. Ice also collected in the opening of the sleeping bag and it was found convenient to fill this opening with a very loose woven dish cloth material, loosely arranged. The water vapour in the exhaled air condensed to ice in this open mesh rather than around the neck of the sleeping bag and was more easily removed. Moreover inspired air was warmed on passing in through this crude heat exchanger and the face, especially the nose, was certainly warmer than without the arrangement. Those who simply withdrew into their bag and closed the neck without any such device had considerable icing up of the necks of their sleeping bags. Sleep was always interrupted by turning over since a conscious effort was needed to turn over in these heavy bags.

The windows of the Snow-cats also iced up inside and had to be scraped regularly. Cab temperature depended on whether the windows were open and the only actual measurements available are - 25°C and - 30°C on entering, and 2.5C at head level rising over an hour to +5°C. The cab floor was always well below freezing point. The tents gradually iced up especially during the later part of the journey between the South Pole and Depot 700 when the altitude rose to a maximum of 3,015m. Several members had painful cold-cracks on the fingers. These healed rapidly in the last days of the journey, when the temperature rose as the party descended some 2,500m down the Skelton Glacier. The ice and

rime on the lower part of the tent walls, and that inside the Snow-cats dropped off during these last few warmer days.

Probably the most important thing was to keep the clothing clean and dry, since damp clothes freeze, and leak heat. This also meant keeping the tent floor and sleeping bags clean. Another important factor to remember was the much increased time needed for even the simplest tasks while encumbered with polar clothing, and the great difficulty of performing accurate delicate movements, or even writing, while wearing several layers of gloves.



Day	Hours	Main P.	Inter	Cat naps	To bed	Get up	Activity
Sunday	9	9	/	/	01·30	07·30	PACKING SLEDGES — DRIVING WEASEL
Monday	7	7	/	/	01·00	08·00	DRIVING WEASEL SNOWCAT RECOVERY—CREVASSE
Tuesday	5½	5½	/	/	02·00	07·30	DRIVING
Wednesday	8½	8½	/	/	24·00	08·30	DRIVING & PRODDING
Thursday	8	8	/	/	23·30	07·30	CREVASSE PRODDING DRIVING
Friday	8	8	/	/	24·00	08·00	PRODDING DRIVING
Saturday	5½	5½	/	/	02·00	07·30	PRODDING DRIVING

FIG V (1)
Typical sleep card. The weight and fat thickness data have been transferred to this card from the card for week 53 in order to show typical readings.

V

DATA COLLECTED IN ANTARCTICA.

(1)

INTRODUCTION

Each man completed a daily record of the clothing he wore outdoors by ticking a list on his sleep card, on which he also marked his sleep for the night before and his activity, and whether he was working indoors or outdoors. (Figure V (1))

The conditions during the crossing were strenuous. Driving was often difficult or dangerous because of sastrugi or crevasses, and blizzards, whiteouts, drift and low temperatures added to the difficulties. The working day was very long, often sixteen hours, and sleeping time was restricted, averaging six hours. On pitching camp at the end of each day's run, the natural wish was for a quick meal and then to get to sleep as soon as possible. Observations and measurements or experiments done in camp were in fact done in time which could have been spent sleeping, and it is not surprising that activities not essential to survival (such as filling up sleep cards) were not always performed with enthusiasm. Records for one man are completely missing for the last six weeks. On average, for the remaining eleven men, not more than four or five days are missing for the crossing period of three months.

The space on the record card for the activity was not large enough, and unfortunately activity records have been missed out for some days by some of the men. As far as possible, evidence of their activity has been collected from other sources such as diaries, tenting partner's records and the log of the journey, and the deficiencies thus made good.

If the clothing records were not completed for a certain day, then that day has been ignored in all work using regression analysis. In a case where there is no information about a man's activity, light work has been assumed. Activity information is missing mainly from the crossing, and it has been assumed unless an activity has been filled in that the men were either driving a vehicle or travelling as a passenger. This is in fact a safe assumption since the activity was the same, day

after day, and was not filled in repetitiously for that reason. When other activities occurred, then the activity of the whole party changed (since all the vehicles kept together) and is recorded in other sleep cards, diaries and the official log kept by the leader. For example, when crevasses were met and probing had to be done, the whole party undertook the work. In the early spring, before the main crossing started, there were several parties working in the field, including the route finding party, and these all kept adequate separate activity records. Further details are given in 'The Crossing of Antarctica' by Sir Vivian Fuchs and Sir Edmund Hillary.

(2) CLIMATIC DATA

Temperature, windspeed, cloud cover, altitude and drift records are available for the whole of the period in Antarctica. (La Grange 1963) No weather records are available at Shackleton for November 1957, but the American station at Ellsworth is only a few miles from Shackleton, and weather records were made there from July 1957 until December 1958. ('Climatological Data for Antarctic Stations' July 1957 to December 1958. Number 1. U.S. Department of Commerce, Weather Bureau.) A comparison of the temperatures at Shackleton with those at Ellsworth for July, August, September and October 1957 shows an agreement within $1^{\circ}C$. The temperature at Ellsworth has therefore been used as approximating to the temperature at Shackleton for November 1957.

The sleep records showed the extent of the working day. The temperature for the day was taken as the average value over the period when the men were not sleeping, and a similar value was taken for the windspeed, cloud cover, altitude and drift.

Radiation and Cloud Cover

Incoming radiation can be a very important factor in personal comfort at various times. (Chrenko & Pugh 1961) For example, there were a few occasions when members worked stripped to the waist at low temperatures because there was

blazing sunshine and no wind. The smallest cloud or a breath of wind caused hurried dressing. Cloud cover and incoming radiation are obviously linked, and although radiation records for the period of the crossing are not complete (owing to the malfunctioning of the instrument) there are full records of cloud cover for the entire period. Cloud cover was measured in eighths.(0 = no cloud, 8 = completely overcast)
A correlation of total solar radiation and cloud cover was made for a period of three months when continuous records for both were available, and the correlation was found to be significant at the 1% level. For the analysis of the crossing data, cloud cover was therefore used as an indication of the radiant energy falling on the men. It was not used for the analysis of the base data.

Sunshine

Daily number of hours of sunshine are available for the period of occupation of Shackleton and South Ice Bases.

Drift

Loose surface snow moves in the wind, and is very unpleasant at head level, and drift was therefore recorded as low drift or high drift. For the purposes of this analysis, drift has been divided into the following categories:-

0 = no drift
1 = low drift sustained over the day
2 = low and high drift on the same day
3 = high drift sustained over the day

(3) CLOTHING

The men were able to choose from the following list of clothing. There was always enough clothing to choose from. A very few articles were added at the South Pole. Spare clothing was carried on the crossing and the men were able to get replacement articles of clothing if their garments became badly soiled e.g. with oil or grease during vehicle maintainence. (although several men kept a special outer garment for this

dirty job) On the crossing it was extremely difficult to change the clothing during the day, and so what was donned in the morning was worn for the whole day.

Clothing	Description
Hands	
Heavy duty gloves	Leather; reinforced; clumsy to use.
Ski leather gloves	Shorter; lighter; still clumsy to use.
Woollen inner gloves	Thumb and one finger separate.
Duffle inner gloves	Woollen felt; only thumb separate.
Silk gloves	All fingers separated; used briefly while manipulating instruments outdoors.
Wristlets (R.A.F. issue)	Fingerless, knitted wool; very useful.
Woollen mitts	Not popular.
Feet	
Duffle slippers	Woollen felt; three sizes to be worn inside each other as a set.
Woollen socks	Ankle length.
Woollen seaboot stockings	Thick knitted wool; knee length.
Mukluk duffle inners	Woollen felt; inners and outers
Mukluk duffle outers	worn together inside mukluks.
Mukluks	Canvas tops with rubber soles.
Felt insoles	Used inside mukluks.
Moccasins	Soft leather; excellent at low temperatures.
Plastic insoles	Used inside moccasins or boots.
Ski boots	Leather with thick rubber soles; not suitable for very low temperatures.
Head	
Balaclava	Woollen knitted
'Fur' hat	Sheep skin lined leather with flaps to cover ears.
Woollen hat	Knitted ski cap
Snow goggles	Obligatory at all times outdoors; blocks ultra violet light.
Blizzard mask	Quite unsuccessful; abandoned.

Upper Trunk	Description
Duffle inner anorak	Rarely used.
Outer anorak	Windproof cotton ventile with hood; worn at base only.
Sledging anorak	Roughly the same as the outer anorak but with wolverine fur edging round hood; a better shape and with zip pockets; the universal outer garment.
Down anorak	Quilted windproof cotton, filled with down; worn at base only.
String vest	Cotton; very important basic garment.
Woollen vest	Short sleeved.
Aertex vest	More popular than wool.
Woollen shirt	-
Cotton shirt	-
Pyjama jacket	Cotton.
Blue seaman's jersey	Thin woven wool with a 'V' neck.
Khaki jersey	Wool with a round neck; army issue; very popular.
White jersey	Thick knitted wool with a roll neck; Royal Navy Submarine issue.
Woollen scarf	Not much used.
Scarf	Loose knitted dish-cloth type material; often used.

Lower Trunk	
Aertex underpants	Universally used.
Short underpants	Short legged; thin woven wool.
Long underpants	Thick knitted tights; wool; excellent in extreme conditions.
Pyjama trousers	Cotton
Battledress trousers	Thick wool; army uniform type; universally worn.
Windproof trousers	Cotton ventile; obligatory outer garment.
Down trousers	Quilted windproof cotton filled with down; occasionally used, at base only; matched down anorak.

See Plates V (1), V (2), V (3) and V (4) for illustrations of representative clothing assemblies

Plate V (1) shows the subject wearing a khaki jersey, battledress trousers and moccasins. The usual underclothing would be:- string vest, short aertex underpants, cotton or wool shirt, socks, and duffle inners under the moccasins. In severe conditions long underpants were worn.

Plate V (2) shows a dark coloured windproof sledging anorak with wolverine edging to hood. The waist is loose and not tucked in and the hood draw string is half tightened. Windproof trousers are shown with the ankle closed by a tape around the outside, closed over the moccasin. Both anorak and trousers are patched and had been worn for over a year. The heavy duty sledging gloves are attached to a lamp wick harness to prevent loss in high winds. Snow goggles complete the assembly which is worn over the clothing shown in Plate V (1). A hat is worn under the anorak hood, and woollen gloves and duffles under the heavy duty leather gloves.

Plate V(2)

Plate V(1)

Plate V (3) shows sheepskin 'fur' hat, light coloured anorak with hood down, draw strings loose, not tucked in, and heavy duty sledging gloves. Light coloured windproof trousers are shown, worn outside mukluks on one leg, and inside on the other. Both arrangements were used.

Plate V (4) shows a down filled anorak and down filled trousers, worn over other clothing. The hood is up over the head and all the draw strings except that around the hood are drawn firm. The hood has a canvas extension to help shield the face from wind. Heavy duty gloves, moccasins and snow goggles complete the assembly.


Plate V(4)


Plate V (3)

Crossing party at the South Pole 19.1.1958 wearing typical outdoor clothing (except for snow goggles).

(4) WEIGHT AND FAT THICKNESS

The fat thickness and weight records were made on most subjects each month for the ten month period at base, and some measurements were made at the South Pole during the crossing.

The subjects were weighed nude, in kilograms. Weighing was carried out late at night before going to bed and after emptying the bladder.

At base an accurate weighing machine was used, but on the crossing only a light weight spring balance of the bathroom scale type was available and was found to be of low accuracy. The logistics of the crossing were absolutely critical and heavy apparatus could not be carried.

The fat thickness was measured on five different points in tenths of a millimetre on each subject. The points were:-

(1) Outer arm, between deltoid insertion and elbow.
(2) Front of chest, lateral clavicular line opposite nipple.
(3) Abdomen, paramedian between costal edge and iliac crest.
(4) Outer leg, one third way down thigh.
(5) Subscapular point.

The mean fat thickness was taken as the arithmetic mean of the measurements on the five sites. The calipers used were simple engineering calipers with flat measuring surfaces (6mm x 15mm) calibrated in 0.2mm divisions which could be read to 0.1mm. They exerted a constant pressure of 15 g/cm^2

(5) SLEEP

Records of sleep were kept by each man for every night using the sleep cards. (Figure V (1)) The page starts at midday on Sunday and ends at midday on the following Sunday. The records made gave the time of going to sleep, the time of getting up and the interruptions of less than half an hour during the main period of sleep. From this, the total number of hours of sleep per night were calculated. The records also gave the 'cat-naps' during the day.

(6) ACTIVITY

Although measurements were made of energy expenditure under different conditions, measurements are not available for all the many different types of activities which the men undertook during their period in Antarctica.

The activities have therefore been ranked into five different groups:-

(1) Sleeping (1.2 Kcal/min)
(2) Sitting (1.9 Kcal/min)
(3) Light work (3.2 Kcal/min)
(4) Medium work (5.6 Kcal/min)
(5) Heavy work (10.0 Kcal/min)

The following list gives examples of the activity groups:-

Examples of 2

Flying

Radio work

Travelling as passenger

Laboratory work

Examples of 3

Vehicle work including workshop repairs, vehicle maintainance, greasing and welding

Photographic work and filming generally

Meteorological observations outdoors

Driving

Examples of 4

Hut building

Crevasse probing

Seismic surveying and shooting

Glaciology

Flag placing when driving in whiteouts

Brake man on the last sledge of a series

General duties

Carpentry outdoors

Preparations of vehicles, planes, refuelling

Examples of 5

Dog sledging

Loading and packing sledges, vehicles, planes

Digging or tunnelling, digging up sledges or stores, pit digging

Sawing snow, drilling snow

Seal hauling (carcasses)

Sawing and cutting frozen seal carcasses

VI PRELIMINARY ANALYSIS

(1) THERMAL INSULATION OF CLOTHING - CONSIDERATION OF METHODS

Before any work could be carried out on the clothing data, some method of estimating the insulation of the clothing assemblies actually worn by the members of this expedition in the field had to be found.

Four methods available for the measurement of clothing insulation were considered. (Newburgh 1949; Goldsmith 1960)

(a) The thermal insulation of single layers of fabric can be measured using an application of Lees' disc apparatus. (Morris G. J. 1953) This however would prove unduly destructive because of the necessity of cutting up the clothing. Records already exist for the insulation of many types of fabric, but it is not possible to combine the individual insulations unless the fabrics have smooth surfaces. (Morris Mary Ann 1955) In any case, the insulation of the multiple layers making up a clothing assembly is not necessarily comparible with the insulation of the clothing assembly when it is worn on the human body.

(b) Siple and Cochran's (1944) technique of measuring the circumference of the limb of a man wearing several layers of clothing so as to estimate the total thickness of dead air enclosed, and thereby estimating the insulation of the assembly, was also discarded partly because of the time factor involved in carrying out measurements for every possible clothing assembly worn by all twelve men on the crossing, and partly because of the variations in circumference during activity.

(c) The number of layers of clothing in an assembly can be counted and the figure taken as related to the thermal insulation of the clothing assembly, and this method has been used empirically by Goldsmith (1960) and later by Palmai (1962) and Lugg (1965).

(d) The measurement of the 'clo value' of whole clothing assemblies on a heated mannikin is a lengthy process, each measurement requiring approximately one working day. The necessary apparatus occupies an entire building with its own staff, and few such institutions exist. (Kerslake 1964) We were extremely fortunate in having twenty eight clothing assemblies measured and the details of these measurements are given in Section VII.

(2) METHOD CHOSEN FOR PRELIMINARY ANALYSIS

It was decided that a 'clo value' analysis of as many clothing assemblies as possible was highly desirable, and method (d) above was set in motion. As this would obviously introduce a considerable delay, it was decided to carry out a preliminary analysis of the clothing data in the mean time, using method (c), a simple 'number of layers' count as a measure of total thermal insulation. This had the added advantage of making possible a comparison of the merits of a full 'clo value' analysis as against a simple layer count, a comparison apparently not hitherto made.

Number of Layers Count for Preliminary Analysis

The body was divided into four sections:-

(a) upper trunk
(b) lower trunk
(c) feet
(d) hands

The layers for the individual sections were counted, and the figure obtained was taken as directly related to the insulation of the sections. The 'total number of layers' on the body was also used as a number related to the insulation of the whole assembly, and this figure always included the number of layers worn on the head. Garments worn in pairs, such as gloves and socks were counted as one garment in all these layer counts.

In this preliminary analysis, windproof anoraks and down anoraks were counted as two layers because of the extreme importance of the outer layers - if windproof - in conserving heat. In later analysis, further weighting of special layers of clothing was investigated and related to the actual 'clo value' measurements when these became available.

(3) ANALYSIS OF CLOTHING DATA

Because the personal exposure of individuals to harsh environmental conditions was longer and more severe during the crossing than at base, it might be expected that evidence of acclimatization would be more marked and easier to detect during this period than any other, and therefore the crossing data was analysed first.

Crossing Data

The number of layers of clothing for each man for each day of the crossing was calculated for each section of the body. All windproof anoraks were counted as two layers. The average number of layers of clothing on the hands for the whole group was then calculated for each week of the crossing. Similarly, the average number of layers worn on the upper trunk, lower trunk and the feet were calculated for the whole group for each week. An average 'total number of layers' for each week was also calculated, and this last figure also included the average number of layers worn on the head by all members during that time.

For the preliminary work on the data, it was necessary to have some measure of the climatic conditions in the form of an index, in order to compare days of similar weather conditions more easily. The best available index is Siple's wind chill factor, which is a function of windspeed and air temperature. (Siple & Passel 1945) Wind chill is the rate of heat removal from the human body by wind and temperature difference, and the formula for it was calculated empirically by Siple.

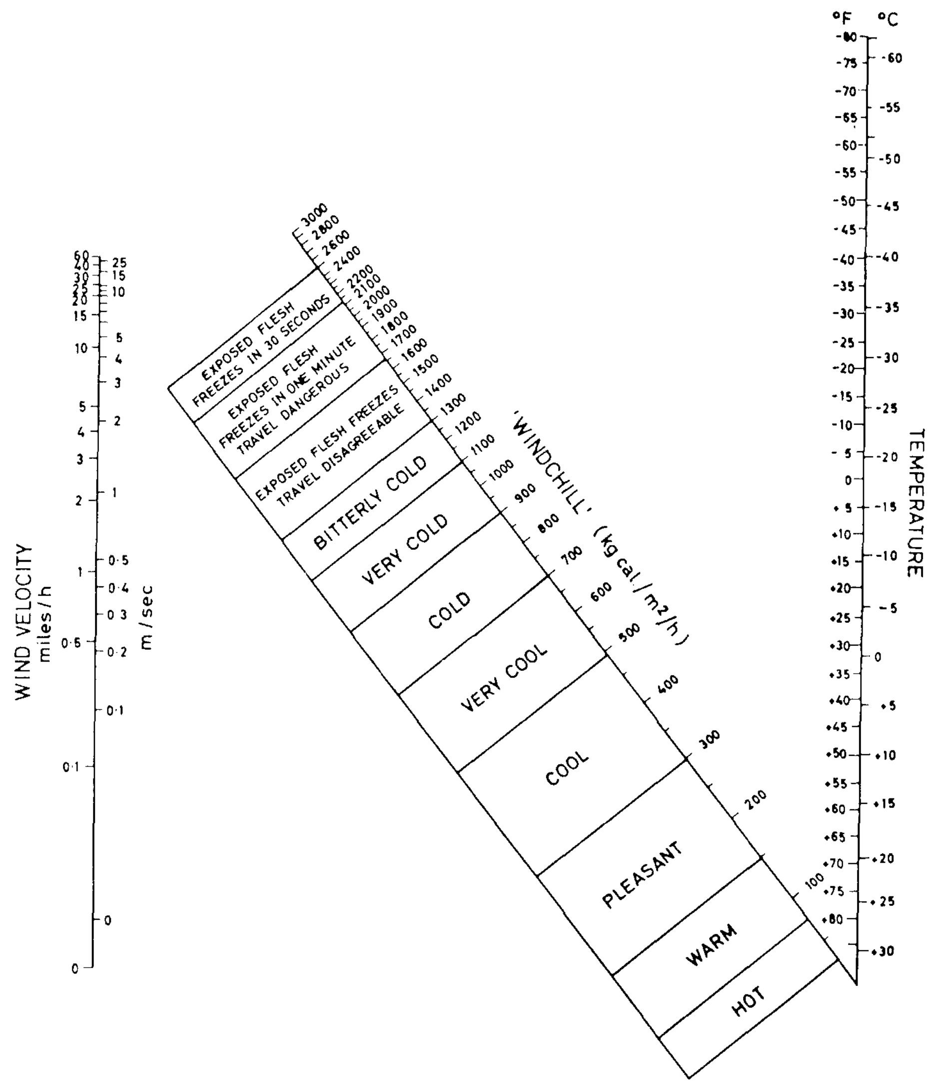


Figure vi(i). Nomogram of wind chill scale. (From Consolazio, Johnson and Marek, 1951. By courtesy of the C. V. Mosby Company)

The formula used is:-

$$H = (\sqrt{v} \times 100 + 10.45 - v) \quad (33 - T_a)$$

Where H = cooling power of the atmosphere in kilogram calories per square metre per hour

v = wind velocity in metres per second

T_a = temperature of the air in degrees centigrade

Figure VI (1) gives the nomogram of the wind chill scale.

There has been criticism of the theoretical basis of Siple's work, (Court 1948, Burton & Edholm 1955, Molnar 1960) and one of the main disadvantages of using Siple's wind chill index is that it takes no account of the sun's radiation. Siple's wind chill factor was calculated for each day of the crossing.

Graphs of clothing worn against time, wind chill against time and temperature against time were plotted for each of the men for the crossing period. Graphs of clothing worn against temperature, and clothing worn against wind chill were also drawn. The aim of these graphs was to give a general understanding of the data before a more complicated analysis was carried out. The correlation between the number of layers worn and wind chill was calculated.

Base Data

For the period at Shackleton Base, i.e. January 1957 to November 1957, the monthly averages of temperature, wind and wind chill were calculated and presented in graphic form along with the monthly averages of the 'total number of layers' of clothing.

The correlation between number of layers and temperature, and the correlation between number of layers and wind chill was then calculated.

The preliminary analysis of the base data was not carried out in as much detail as that of the crossing data. Monthly averages were only used to save calculation time.

VII C L O V A L U E M E A S U R E M E N T S

(1) INTRODUCTION

The heat loss from the body via the skin is in part by radiation and convection, and in part by evaporation of water. If there is no active sweating, the evaporation loss can be taken as a constant fraction of the whole. The thermal insulation of clothing is concerned with the non-evaporative heat losses from the body, and is given by.-

$$I_{cl} + I_A = \frac{(T_S - T_A)\ S}{H} \qquad \text{(VII (1))}$$

where I_{cl} = the insulation of the clothing
I_A = the insulation of the air
T_S = the temperature of the skin (or surface of mannikin
T_A = the ambient air temperature in $^{\circ}C$
H = the rate of heat loss in Kcal/hr
S = the surface area of the body in square metres

The thermal insulation of clothing is usually measured in 'clo units'. The definition of the clo unit in terms of fundamental units is:-

$$1 \text{ clo} = 0.18 \frac{^{\circ}C}{\text{Kcal}/m^2/\text{hr}}$$

The factor 0.18 was derived from the following conditions:-

Metabolism of a resting/sitting man	=	50 Kcal/m^2/hr
Therefore heat loss of a comfortably dressed, resting/sitting man	=	50 Kcal/m^2/hr
(indoor ambient temperature 21°C; air movement 10 cm/sec; relative humidity less than 50%)		
Allowing 25% of 50 Kcal/m^2/hr for the evaporative heat loss, then the non-evaporative heat loss of a comfortably dressed resting/sitting man	=	38 Kcal/m^2/hr
Average skin temperature of a comfortable man	=	33°C

Inserting these values in equation (VII (1)), we have:-

$$I_{cl} + I_A = \frac{33 - 21}{38} \quad \frac{^{\circ}C}{Kcal/m^2/hr} = 0.32 \quad \frac{^{\circ}C}{Kcal/m^2/hr}$$

However, under these conditions of air movement, humidity and temperature,

$$I_A = 0.14 \quad \frac{^{\circ}C}{Kcal/m^2/hr}$$

(Winslow, Gaggem & Herrington 1940)

$$\text{Therefore } I_{cl} = 0.32 - 0.14 \quad \frac{^{\circ}C}{Kcal/m^2/hr}$$

Therefore 1 clo unit is defined as:- $\quad 0.18 \quad \dfrac{^{\circ}C}{Kcal/m^2/hr}$

The illustration of the clo unit is usually quoted in the following form:-

"One clo unit of thermal insulation will maintain a resting/sitting man whose metabolism is 50 $Kcal/m^2/hr$ indefinately comfortable in an environment of 21°C, relative humidity less than 50%, and air movement 10 cm/sec"

This subject is usefully discussed in detail by Burton and Edholm "Man in a Cold Environment" (1955)

The thermal insulation of a clothing assembly can be measured on a heated mannikin, and, although there has been some critioism of the method, it remains a very useful tool for comparing the insulation of different assemblies, and cuts down much of the inconvenience involved in doing similar tests on human beings. (Wickett & Soper 1956)

Twenty four clothing assemblies were sent to the Wright-Patterson Air Force Base, U.S.A. for 'clo value' analysis of the total assemblies. Four basic clothing assemblies were tested at the R.A.F. Institute of Aviation Medicine, Farnborough, England, under different conditions of windspeed, and clo values were calculated for each section of the body.

(2) WORK CARRIED OUT AT WRIGHT-PATTERSON AIR FORCE BASE

The twenty four assemblies sent to the Wright-Patterson Air Force Base consisted of twelve pairs, each pair (A & B) representing a maximum and minimum clothing assembly worn by each of the twelve men on the crossing. A list of the twenty four clothing assemblies is given in Table VII (1). Further descriptions of the articles of clothing tested are given in Section V (3).

The tests were made on a standing thermal copper man. The surface area of the copper mannikin was maintained at a uniform temperature by adjusting the energy supply to fifteen separate electrically heated surface areas.

The combined insulation of the clothing and the air was then calculated from equation (VII (1)).

$$I_A + I_{cl} = \frac{(T_S - T_A)\ S}{H} \times \frac{1}{0.18} \text{ clo units}$$

(0.18 is the conversion factor from $\frac{{}^{o}C}{Kcal/m^2/hr}$ to clo units)

The insulation of the air was then subtracted from the calculated figure to give the insulation of the clothing assembly I_{cl}

Table VII (2) gives a list of the clo values of the assemblies tested with the range of temperatures and wind for the days when the clothing was worn. Each clo value given is the mean of two readings. The insulation of the assemblies tested, ranged from 2.76 clo units to 1.36 clo units.

	1A	2A	3A	4A	5A	6A	7A	8A	9A	10A	11A	12A
Hands												
Silk Gloves	1	-	-	1	-	-	-	-	-	-	-	-
Woollen Inner Gloves	1	1	1	1	1	-	1	-	1	-	1	1
Heavy Duty Gloves	1	1	1	-	-	1	1	1	-	1	1	1
Woollen Wristlets	-	-	1	-	-	-	-	-	-	-	1	-
Duffle Inner Gloves	-	1	1	1	-	1	1	1	1	1	-	1
Woollen Mitts	-	-	-	1	1	-	-	-	-	-	-	-
Ski Leather Gloves	-	-	-	1	-	-	-	-	1	-	-	-
Feet												
Short Woollen Socks	2	2	2	3	2	2	2	2	3	2	3	2
Plastic Insoles	1	-	1	-	1	-	1	-	1	-	1	1
Felt Insoles	-	1	-	-	-	1	-	-	-	1	-	-
Duffle Slippers	2	-	1	-	1	1	1	2	1	-	2	-
Moccasins	1	-	1	-	1	-	1	-	1	-	1	1
Mukluk Duffle Outers	1	1	-	1	1	1	1	1	1	1	-	1
Mukluk Duffle Inners	-	1	1	1	1	1	1	1	-	1	-	1
Mukluks	-	1	-	1	-	1	-	1	-	1	-	-
Ski Boots	-	-	-	-	-	-	-	-	-	-	-	-
Head												
Balaclava	1	1	-	1	-	1	1	1	1	1	-	1
Fur Hat	-	-	1	-	1	-	-	-	-	-	1	-
Upper Trunk												
String Vest	1	1	2	1	1	1	1	1	1	1	1	1
Woollen Vest	1	-	-	1	1	1	1	1	1	1	-	1
Woollen Shirt	1	1	1	1	1	1	1	1	1	1	1	1
Thick Woollen Jersey	2	3	2	2	1	1	2	2	2	2	2	1
Sledging Anorak	1	1	1	1	1	1	1	1	1	1	1	1
Scarf	1	-	-	1	1	-	1	1	1	1	-	-
Cotton Pyjama Top	-	-	1	-	-	-	-	-	-	-	-	-
Lower Trunk												
Short Woollen Underpants	1	-	-	1	1	-	1	1	1	1	1	-
Long Woollen Underpants	1	1	1	1	1	1	1	-	1	2	1	1
Battledress Trousers	1	1	1	1	1	1	1	1	1	1	1	1
Windproof Trousers	1	1	1	1	1	1	1	1	1	1	1	1
Cotton Pyjama Bottom	-	-	1	-	-	-	-	-	-	-	-	-
Clo Values	2.39	2.42	2.64	2.39	2.76	2.34	2.47	2.14	2.48	2.56	2.33	2.36

Table VII (1a) Clo Values of Assemblies Tested at Wright-Patterson Air Force Base, U.S.A.

	1B	2B	3B	4B	5B	6B	7B	8B	9B	10B	11B	12B
Hands												
Silk Gloves	-	-	-	1	-	-	-	-	-	-	-	-
Woollen Inner Gloves	-	-	1	-	1	1	-	-	-	-	-	-
Heavy Duty Gloves	1	1	1	1	-	-	1	1	1	-	1	-
Woollen Wristlets	-	-	1	-	-	-	-	-	-	-	-	-
Duffle Inner Gloves	-	-	-	-	-	-	1	1	1	-	1	-
Woollen Mitts	-	-	-	-	-	-	-	-	-	-	-	-
Ski Leather Gloves	-	-	-	-	-	-	-	-	-	-	-	-
Feet												
Short Woollen Socks	2	2	2	2	1	2	2	1	2	2	1	2
Plastic Insoles	1	-	1	-	1	-	-	-	-	1	-	1
Felt Insoles	-	-	-	1	-	-	1	-	-	-	-	-
Duffle Slippers	-	-	1	-	2	-	-	1	1	-	-	-
Moccasins	-	-	1	-	1	-	-	1	-	1	-	1
Mukluk Duffle Outers	-	1	1	-	1	1	-	1	-	1	-	1
Mukluk Duffle Inners	-	1	-	1	-	-	1	1	-	1	-	1
Mukluks	-	1	-	1	-	1	1	-	1	-	-	-
Ski Boots	1	-	-	-	-	-	-	-	-	-	1	-
Head												
Balaclâva	1	1	-	1	1	1	1	1	-	1	-	1
Fur Hat	-	-	1	-	-	-	-	-	-	-	1	-
Upper Trunk												
String Vest	1	1	1	1	1	1	1	1	1	1	1	1
Woollen Vest	1	-	-	1	1	1	-	-	1	1	1	1
Woollen Shirt	1	1	1	1	-	1	1	1	1	1	-	1
Thick Woollen Jersey	-	1	1	-	1	-	1	1	-	1	1	1
Sledging Anorak	1	1	-	1	1	1	1	1	1	-	1	-
Scarf	-	-	-	-	-	-	1	-	1	-	-	-
Cotton Pyjama Top	-	-	-	-	-	-	-	-	-	-	-	-
Lower Trunk												
Short Woollen Underpants	1	-	1	1	1	-	1	1	1	1	1	-
Long Woollen Underpants	-	1	-	1	-	1	-	-	1	1	-	1
Battledress Trousers	1	1	1	1	1	-	1	1	1	1	1	1
Windproof Trousers	1	1	1	1	1	1	1	1	1	-	1	1
Cotton Pyjama Bottom	-	-	-	-	-	-	-	-	-	-	-	-
Clo Values	1.78	1.96	1.64	1.9	1.90	1.68	1.94	1.96	1.6	1.36	1.7	2.33

Table VII (1b) Clo Values of Assemblies Tested at Wright-Patterson Air Force Base, U.S.A.

Assembly	Subject Number	Clo Value	Average Temp. (°C)	Average Wind (m/sec)	Average Wind Chill (Kcal/m^2/hr)
1A	8	2.39 (±0.09)	-31.4	5.4	1822
2A	5	2.42 (±0.01)	-26.0	5.8	1628
3A	1	2.64 (±0.02)	-20.9	1.3	1108
4A	11	2.39 (±0.01)	-31.4	5.4	1822
5A	2	2.76 (±0.05)	-26.7	2.3	1390
6A	12	2.34 (±0.02)	-22.4	4.4	1497
7A	4	2.47 (±0.08)	-30.3	7.2	1904
8A	9	2.14 (±0.01)	-30.3	7.2	1904
9A	6	2.48 (±0.05)	-27.5	5.3	1680
10A	3	2.56 (±0.07)	-28.2	6.2	1794
11A	10	2.33 (±0.05)	-27.1	2.2	1387
12A	7	2.36 (±0.04)	-24.1	4.5	1299
1B	8	1.78 (±0.15)	- 7.5	3.9	846
2B	5	1.96 (±0.01)	- 8.3	9.0	1299
3B	1	1.64 (±0.02)	-16.6	1.6	1066
4B	11	1.90 (±0.06)	-11.0	7.7	1342
5B	2	1.90 (±0.03)	-17.2	5.2	1408
6B	12	1.68 (±0.03)	-12.5	0	475
7B	4	1.94 (±0.06)	-16.6	1.6	1066
8B	9	1.96 (±0.04)	- 3.9	3.9	950
9B	6	1.60 (±0.04)	-15.3	6.2	1407
10B	3	1.36 (±0.02)	-20.9	0	555
11B	10	1.70 (±0.01)	- 8 3	9.0	1299
12B	7	2.33 (±0.17)	-16.6	1.6	950

Table VII (2) The Clo Values of the Assemblies Tested at the Wright-Patterson Air Force Base with the Average Temperatures, Windspeeds and Wind Chill Values on the Days when the Clothing was Worn.

The average value of the assemblies in the 'A' group was 2.4 (S.D. $\pm$ 0.16) and the average clo value of the assemblies in the 'B' group was 1.8 (S.D. $\pm$ 0.21). It can be seen that the average difference between the two groups is 0.6 clo units, and this gives an indication of the difference in the insulation of the maximum and minimum clothing assemblies which were worn by the men on the crossing.

The table and the derived clo values show the considerable increase in thermal insulation given by the wearing of long underpants. This was well recognised by the men during the expedition, and reflected in a telegram, widely publicised at the time, and sent by the members of the Advanced Party on first establishing wireless communication with the outside world. Having survived unusually harsh environmental conditions during the first winter, their first message ended "Long Johns for Ever."

Layer Counting

The number of layers in each clothing assembly was counted using the following groupings:-

(1) All garments 1 layer
(2) Anorak 2 layers; all remaining garments 1 layer
(3) Anorak 2 layers, windproof trousers 2 layers; all remaining garments 1 layer
(4) Anorak 2 layers, long underpants 2 layers; all remaining garments 1 layer
(5) Anorak 2 layers, long underpants 2 layers, windproof trousers 2 layers, all remaining garments 1 layer
(6) Anorak 2 layers, long underpants 2 layers, windproof trousers 2 layers, wool vest 2 layers; all remaining garments 1 layer
(7) Anorak 2 layers, outer gloves 2 layers; all remaining garments 1 layer
(8) Anorak 2 layers, outer gloves 2 layers, long underpants 2 layers; all remaining garments 1 layer

For each group, the regression of clo value on 'total number of layers' was calculated. The regression of clo value on 'total number of layers' counted as in group '1' gave a correlation coefficient r of 0.68. A significant improvement in the

GRAPH OF CLO VALUE AGAINST TOTAL NUMBER OF LAYERS FOR 24 ASSEMBLIES AND FOR 2 DIFFERENT LAYER COMBINATIONS.

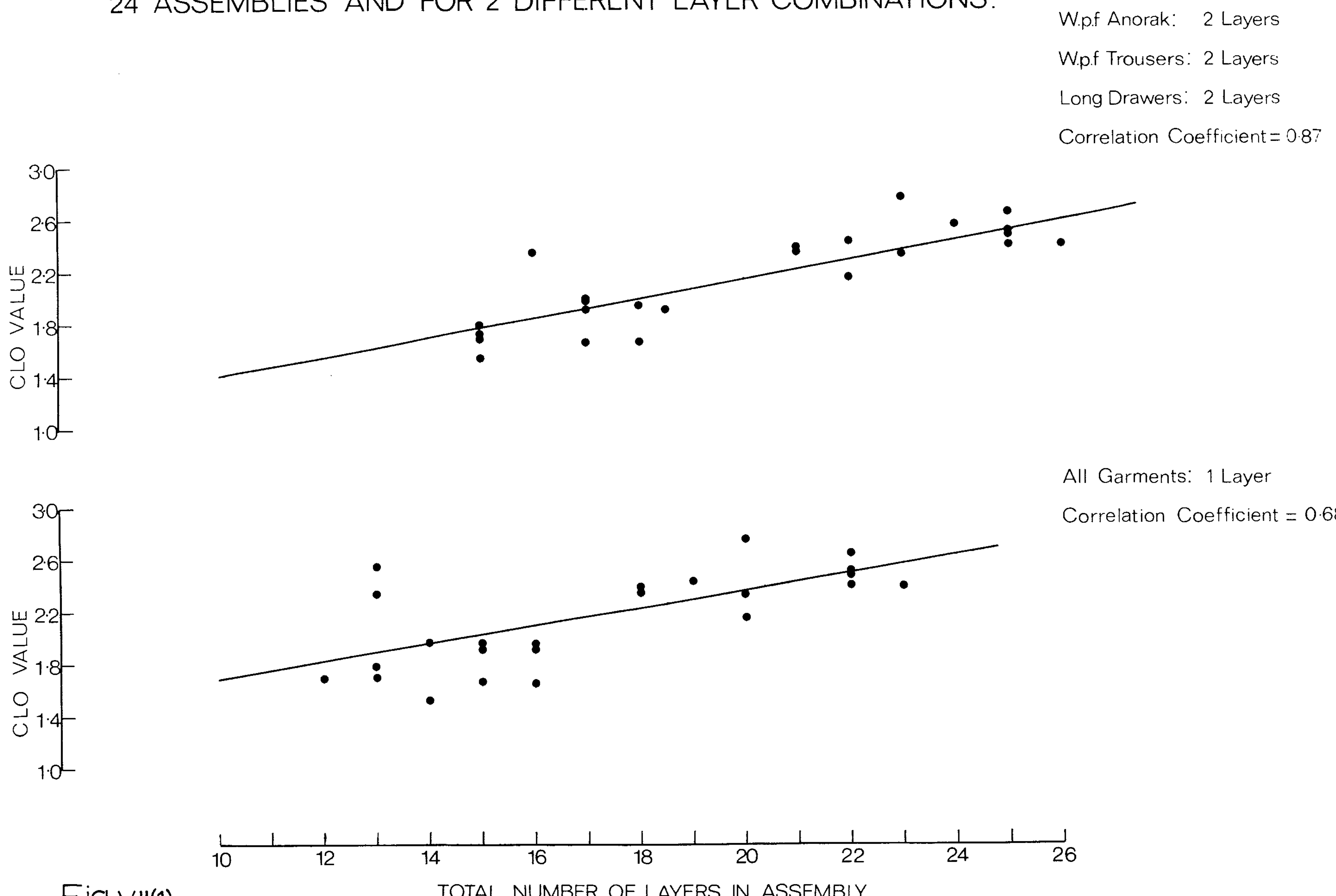


Fig VII(1)

correlation was made when an outer anorak was counted as two layers (group 2) ($r = 0.83$). However, the best correlation was obtained when the 'total number of layers' were counted as in group (5)* (anorak 2 layers, windproof trousers 2 layers, long underpants 2 layers) (Figure VII (1)). In this case the correlation coefficient was 0.87 and the standard error of estimate was 0.15. This means that in predicting the clo value of an assembly from the 'total number of layers' in the assembly (counted as in group 5) we would be correct 95% of the time in claiming that the estimated value lies within 0.29 of the actual value. The regression equation in this case was:-

$$C = 0.078L + 0.6$$

(where C = clo value of assembly;
L = 'total number of layers' in assembly)

The preliminary analysis of the clothing data was carried out before these clo values were available, and the outer anorak was counted as two layers because of the obvious importance of the outer windproof layer in conserving heat. The results of this section confirm this first empirical approach.

(3) WORK CARRIED OUT AT R.A.F. INSTITUTE OF AVIATION MEDICINE, FARNBOROUGH

Several tests were carried out at Farnborough using their heated iron mannikin. (Kerslake 1964) The mannikin is divided into eighteen sections, each of which is controlled so that the relation between local surface temperatures and local heat loss is the same as that determined experimentally on a human subject whose mean skin temperature is 33°C.

The insulation of the clothing assemblies was determined using the following equation:-

$$I_{cl} = \frac{T_S - T_{cl}}{H} \times \frac{S}{0.18} \text{ clo} \qquad \text{(VII (3))}$$

where I_{cl} = Insulation of clothing assembly

T_{cl} = Average temperature of clothing ($^{\circ}C$)

T_S = Average skin temperature of mannikin ($^{\circ}C$)

H = Rate of heat loss from mannikin in Kcal/hr

S = Surface area of mannikin (m^2)

$$1 \text{ clo} = \frac{0.18^{\circ}C}{Kcal/m^2/hr}$$

This equation is different from equation VII (1) because in the Farnborough tests, outside clothing temperatures were measured. However, the ambient air temperature was also measured and there was no significant difference in the thermal insulations of the assemblies tested when they were calculated using equation VII (1) and equation VII (3)

The insulation of the upper trunk, lower trunk, feet and hand clothing was also calculated for each assembly using the same formula as above, but with the values referred to the individual sections of the assembly. Tables VII (3) to VII (6) give the results of these tests. When calculating the insulation of the total assembly, the heat loss from the head was not included in the total heat loss from the mannikin (H). This was reasonable because the unusually cold face of the mannikin did not behave in the same way as that of a human.

Clothing assembly '1' was worn by subject number 10 on days when the temperature was approximately $-30^{\circ}C$ and the wind was approximately 9 m/sec. The measured clo value of the assembly was 1.4 clo. It was tested at windspeeds of 2 m/sec and 4 m/sec, and there was no significant difference in the total insulation under the two conditons. It was also tested with a windspeed of 4 m/sec and with the anorak waist draw string undone and with the hood down. This did not significantly change the insulation of the whole assembly, but the insulation of the upper trunk decreased by 0.5 clo units when the anorak hood was down and the draw string was undone.

It was not possible to obtain greater windspeeds because of the fixed temperature of the wind chamber for each individual test. This temperature could not be altered because of the necessity of keeping the average skin temperature of the heated mannikin at approximately 33°C to ensure that it behaved in the same way as a thermally comfortable human subject.

Clothing assembly '4' was the same as clothing assembly '3' with an additional down jacket and an additional pair of down trousers. The increase in insulation due to this change was 1.3 clo. The insulation of the upper trunk clothing increased by 2.0 clo and that of the lower trunk clothing by 1.8 clo. Assembly '4' was worn in temperatures of -50°C to -60°C. (see Section X)

It is obvious from these results that the hands were less protected than all other parts of the body.

Clothing worn on:-

<u>Hands</u>

1 pair woollen mitts

1 pair heavy duty gloves

<u>Feet</u>

2 pairs short woollen socks

2 pairs duffle slippers

1 pair moccasins

1 pair plastic insoles

<u>Head</u>

1 balaclava

<u>Upper Trunk</u>

1 string vest

1 woollen shirt

1 thick woollen jersey

1 sledging anorak

<u>Lower Trunk</u>

1 pair short underpants

1 pair battledress trousers

1 pair windproof trousers

(1) The shirt was worn back to front

(2) One side of the anorak was unpicked and sewn up again when it was on the dummy

(3) The anorak draw string was done up

(4) The anorak hood was up

(5) Heat losses from the head were omitted in calculating the the insulation of the total assembly

Insulation of total assembly	=	1.4 clo
Insulation of upper trunk clothing	=	1.6 clo
Insulation of lower trunk clothing	=	1.6 clo
Insulation of hand clothing	=	0.5 clo
Insulation of foot clothing	=	1.4 clo

<u>Table VII (3) Clothing Assembly '1' Tested at Farnborough</u>

Clothing worn on:-

<u>Hands</u>

1 pair woollen mitts

1 pair heavy duty gloves

<u>Feet</u>

2 pairs short woollen socks

2 pairs duffle slippers

1 pair moccasins

1 pair plastic insoles

<u>Head</u>

1 balaclava

<u>Upper Trunk</u>

1 string vest

1 woollen shirt

1 thick woollen jersey

1 sledging anorak

1 down jacket

1 scarf

<u>Lower Trunk</u>

1 pair short underpants

1 pair battledress trousers

1 pair windproof trousers

(1) The shirt was worn back to front

(2) One side of the anorak was unpicked and swen up again when it was on the dummy

(3) The anorak draw string was done up

(4) The anorak hood was up

(5) To fit the down jacket on the mannikin, it was put on back to front

(6) Heat losses from the head were omitted in calculating the insulation of the total assembly

Insulation of total assembly	=	2.7 clo
Insulation of upper trunk clothing	=	2.7 clo
Insulation of lower trunk clothing	=	2.3 clo
Insulation of hand clothing	=	0.7 clo
Insulation of foot clothing	=	2.8 clo

<u>Table VII (4) Clothing Assembly '2' Tested at Farnborough</u>

Clothing worn on:-

Hands

1 pair woollen mitts

1 pair heavy duty gloves

Feet

2 pairs short woollen socks

2 pairs duffle slippers

1 pair moccasins

1 pair plastic insoles

Head

1 balaclava

Upper Trunk

1 string vest

1 woollen shirt

2 thick woollen jerseys

1 sledging anorak

Lower Trunk

1 pair short underpants

1 pair long underpants

1 pair windproof trousers

1 pair battledress trousers

(1) The shirt was worn back to front

(2) One side of the anorak was unpicked and sewn up again when it was on the dummy

(3) The anorak hood was up

(4) The anorak draw string was done up

(5) Heat losses from the head were omitted in calculating the insulation of the total assembly

Insulation of total assembly	=	1.8 clo
Insulation of upper trunk clothing	=	2.2 clo
Insulation of lower trunk clothing	=	2.1 clo
Insulation of hand clothing	=	0.5 clo
Insulation of foot clothing	=	2.0 clo

Table VII (5) Clothing Assembly '3' Tested at Farnborough

Clothing worn on:-

<u>Hands</u>

1 pair woollen mitts

1 pair heavy duty gloves

<u>Feet</u>

2 pairs short woollen socks

2 pairs duffle slippers

1 pair moccasins

1 pair plastic insoles

<u>Head</u>

1 balaclava

<u>Upper Trunk</u>

1 string vest

1 woollen shirt

2 thick woollen jerseys

1 sledging anorak

1 down jacket

<u>Lower Trunk</u>

1 pair short underpants

1 pair long underpants

1 pair windproof trousers

1 pair battledress trousers

1 pair down trousers

(1) The shirt was worn back to front

(2) One side of the anorak was unpicked and sewn up again when it was on the dummy

(3) The anorak draw string was done up

(4) The anorak hood was up

(5) Down trousers worn on top of windproof trousers

(6) Down jacket worn back to front on top of windproof anorak

(7) Heat losses from the head were omitted in calculating the insulation of the total assembly

Insulation of total assembly	=	3.1 clo
Insulation of upper trunk clothing	=	4.2 clo
Insulation of lower trunk clothing	=	3.9 clo
Insulation of hand clothing	=	0.7 clo
Insulation of foot clothing	=	2.1 clo

<u>Table VII (6) Clothing Assembly '4' Tested at Farnborough</u>

(4) COMPARISON OF RESULTS FROM FARNBOROUGH WITH THOSE FROM THE WRIGHT-PATTERSON AIR FORCE BASE

Comparing the clo values of assemblies tested at Farnborough with those tested at the Wright-Patterson Air Force Base, it can be seen that there are differences between them. No two assemblies tested at both places were identical, but certain comparisons can be made.

Compare clothing assembly (5B) tested at the Wright-Patterson Air Force Base with assembly '1' tested at Farnborough. The clothing worn on the head and lower trunk was the same in each assembly. An extra pair of woollen socks was worn in assembly '1' but this was balanced by a pair of mukluk duffle outer is (5B). Clothing assembly '1' also had an extra pair of heavy duty gloves and an extra shirt. In other words, although clothing assembly '1' consisted of more clothing than clothing assembly (5B), the measured clo value of assembly '1' (1.4 clo) was less than that of assembly (5B) (1.9 clo).

A similar comparison can be made with clothing assembly '1' and clothing assembly (8B).

Compare clothing assembly '3' tested at Farnborough with clothing assembly (11A) tested at the Wright-Patterson Air Force Base. The upper trunk and the lower trunk clothing was identical. A hat was included in assembly (11A) as opposed to a balaclava in assembly '3'. An extra pair of wristlets was included on the hands in assembly (11A) and also an extra pair of short socks was worn in this assembly. However, this slight addition in clothing in assembly (11A) does not explain the difference in clo values. (assembly 11A was 0.53 clo greater than assembly '3')

Despite the difference between the groups, the results from the two sources can be used for comparisons within the two separate groups. The differences are discussed further in Section X.

VIII C O M P U T E R A N A L Y S I S O F D A T A

(1) TECHNIQUES OF COMPUTER ANALYSIS

The computer analysis was performed on an ICL System 4-70 machine. This machine has a core of 448 K, 8 bit bytes ($K = 2^{10}$) of 1 μsec cycle time, and is oriented for multiaccess. The data was stored on a replaceable disc with a capacity of 7 megabytes and a speed of 156 kilobytes/second and on a magnetic tape with a capacity of 20 megabytes and a speed of 60 kilobytes/second. The programs were compiled by the Fortran Compiler of the ICL J-Operating System, and they were written in J-Level Fortran which is a version of Fortran IV.

Preparation of Data for Computer

The following data was coded onto computer cards for each man for each day of the expedition:-

(1) Serial number of man
(2) Date
(3) Week number
(4) Whether working outdoors or not
(5) Base (geographical)
(6) Activity of man
(7) Clothing worn on head
(8) Clothing worn on upper trunk
(9) Clothing worn on feet
(10) Clothing worn on lower trunk
(11) Clothing worn on hands

If the man was working indoors, his clothing assembly was not recorded. One column of the computer card was reserved for each article of clothing. Table VIII (1) gives a detailed description of the data on the card. The following codes were used for the bases:-

(1) Shackleton
(2) Scott Base
(3) South Ice
(4) South Pole
(5) Halley Bay
(6) On Crossing

The activity of the man was ranked into five different groups. (Budd 1966)

(1)	Sleeping	1.2 Kcal/min
(2)	Sitting	1.9 Kcal/min
(3)	Light work	3.2 Kcal/min
(4)	Medium work	5.6 Kcal/min
(5)	Heavy work	10.0 Kcal/min

Examples of the above groups are given in the Data Section (V (6))

The weather data was also coded onto computer cards, and this was divided into:-

Weather at Shackleton Base
Weather at South Ice Base
Weather on the Crossing

For each division, the following data was coded onto computer cards, one for each day's weather:-

(1) Base (geographical)
(2) Week number
(3) Date
(4) Temperature ($^{\circ}C$)
(5) Wind (knots)
(6) Wind chill ($Kcal/m^2/hr$)
(7) Altitude (metres)
(8) Cloud cover in eighths
(9) Drift

Because of the difficulty of handling such a large amount of data on computer cards, the data was transferred onto magnetic disc and magnetic tape. A direct access file was therefore set up on magnetic disc for each member of the expedition, containing all that man's clothing and activity data. Meanwhile, weather data was transferred onto magnetic tape.

Columns	
1 - 2	Serial Number of Man (Integer)
3 - 4	Week Number (Integer)
5 - 6	Day (Integer)
7 - 8	Month (Integer)
9 - 10	Year (Integer)
11	Reserve
12	Whether Outdoors or not; 1 = Indoors; 0 = Outdoors
13 - 21	Reserve
22	Code for Geographical Base (Integer)
23 - 29	Reserve
30	Code for Activity (Integer)

Clothing Data

Data entered as '1' or '0'

1 = garment worn

0 = garment not worn

31	Balaclava
32	Hat
33	Reserve
34	Ear Muffs
35	Blizzard Mask
36	Reserve
37	Scarf
38	Reserve
39	Nylon Pile Anorak
40	Aertex Vest
41	Woollen Vest
42	String Vest
43	Shirt
44	Jersey
45	Inner Anorak
46	Outer Anorak
47	Sledging Anorak
48	Down Jacket
49	Pyjama Jacket
50	Overalls
51	Woollen Socks
52	Plastic Insoles
53	Duffle Slippers
54	Mukluk Duffle Inners
55	Mukluk Duffle Outers
56	Ski Boots/Everest Boots
57	Mukluks
58	Rubber Boots
59	Moccasins
60	Sealskins
61	Short Underpants
62	Long Underpants
63	Battledress Trousers
64	Windproof Trousers
65	Down Trousers
66	Pyjama Trousers
67	Nylon Pile Trousers
68	Woollen Mitts
69	U.S. Army Gloves/R.A.F. Gloves
70	Wristlets
71	Silk Gloves
72	Woollen Inner Gloves
73	Duffle Inner Gloves
74	Heavy Duty Gloves
75	Ski Leather Gloves
76 - 80	Reserve

Table VIII (1) Computer Card Coding for Clothing and Activity Data

It was then possible to find for any man's clothing record (on magnetic disc) the corresponding day's weather data. (on magnetic tape)

The weight and fat thickness records for the twelve men were also coded onto computer cards.

(2) PROGRAM TO PERFORM MULTIPLE LINEAR REGRESSION

The multiple linear regression program consisted of a main routine, a data input sub-routine and four sub-routines, from the I B.M. System/360 Scientific Sub-routine Package (Version III)

The four sub-routines are.-

Corre - calculates means, standard deviations and correlations.

Order - chooses dependent variable and a subset of independent variables from a larger set of variables.

Minv - inverts correlation matrix of the subset selected by order.

Multr - computes the regression coefficients.

The sub-routine Corre was modified to accept missing records and calculate the correct means and standard deviations for the modified data.

Each set of clothing records for the twelve men was stored on different direct access data sets on disc, and the weather records were stored on magnetic tape. The main routine read the data cards which specified which man's clothing records were to be read from the disc, and which variable was the dependent variable and which were the independent variables in the multiple regression analysis. It then called the sub-routines to calculate the means, the standard deviations, simple and multiple correlation coefficients, regression coefficients, t-values and the analysis of variance for the multiple regression, and printed out the results.

The data input sub-routine was called by Corre which requires one record of dependent and independent variables at a time. i.e. one day's weather and the corresponding clothing worn by one man.

These variables were obtained from disc and magnetic tape by the data input sub-routine, and stored in an array D. The data input sub-routine read the clothing data record for one day from the specified data set on disc, and the weather data for one day from magnetic tape. If there were no weather records for a certain day, the following day's clothing and weather records were read.

The sub-routine checked that the weather record and the clothing record were for the same day and for the same base. If they were not, it printed out an error message and the program stopped.

Each clothing record on disc contained the information in Figure VIII (1), and each weather record on magnetic tape contained the information listed on page VIII.2.

For each garment, either '1' or '0' was entered in the record. (1 if the garment was worn on the day and 0 if not worn) For all garments which were to be counted as two layers, the relevant number in the record was multiplied by two. The garments which were counted as two layers were:- nylon pile anorak; sledging anorak; down jacket; long drawers; windproof trousers; down trousers and nylon pile trousers.

The number of layers on the upper trunk, lower trunk, feet and hands were calculated, and also the 'total number of layers' on the body. (including the head)

The necessary variables were then stored in the array D and returned to the sub-routine Corre. These were:-

D (1) = Temp $^{\circ}C$

D (2) = Wind (knots)

D (3) = Wind chill (Kcal/m^2/hr)

D (4) = Altitude (metres)

D (5) = Activity

D (6) = Reserve

D (7) = Reserve

D (8) = Number of layers on upper trunk

D (9) = Number of layers on feet

D (10) = Number of layers on lower trunk

D (11) = Number of layers on hands

D (12) = Total number of layers including number of layers on head

D (13) = Number of days from start date of particular period of analysis

D (14) = Cloud cover

D (15) = Drift

(3) ANALYSIS OF CLOTHING DATA

Using the ICL System 4/0 Computer, a full analysis was carried out on the clothing data to discover:-

(a) Whether a relationship existed between climatic stress and the clothing worn, and if so, on what variables the clothing worn depended.

(b) Why the clothing varied from one individual to another under similar conditions.

(c) Whether there was any evidence of acclimatization to cold.

<u>Analysis of Variance</u>

The clothing data worn on the crossing was examined for differences between the clothing worn on successive days by the same man, and for differences between the clothing worn on the same day by different men, using a two factor analysis of variance. (i.e. the 'between men' and the 'between days' difference) (Snedecor & Cochran 1967)

Differences Between Men During the Crossing

To investigate the difference in clothing worn by the men, the weather on the crossing was divided into three categories, as follows.-

	Temperature Range	Wind Range
Medium conditions	$0^{\circ}C$ to $-10^{\circ}C$	0 to 3 m/sec
Medium Severe Conditions	$-10^{\circ}C$ to $-20^{\circ}C$	4 to 8 m/sec
Severe Conditions	$-20^{\circ}C$ to $-30^{\circ}C$	9 to 13 m/sec

A day was picked out which satisfied each weather condition, and the 'total number of layers' of clothing was counted for each man for that day. The weight and fat thickness of each man was taken as the measurement made nearest to the date chosen.

A multiple regression analysis was carried out for one day in each category with 'total number of layers' worn on any one day as the dependent variable, and with a combination of:-

(1) Age
(2) Weight
(3) Mean fat thickness
(4) Surface area
(5) Activity
(6) Height

as the independent variables. As surface area is a function of height and weight, it can only be used as an independent variable in the regression analysis when height and weight are not included.

The average value of the 'total number of layers' for the whole period of the crossing was calculated for each man. Similar multiple regression was carried out with this average value as the dependent variable.

Daily Changes in Clothing for Each Man During the Crossing and at Base.

The results of the 'clo value' analysis carried out at the Wright-Patterson Air Force Base suggested that in fact layer counting was a reasonable technique to use. The 'layer counting method' of obtaining an estimate of the thermal insulation of an assembly was therefore still used for this analysis, but the following garments were counted as two layers:- outer and down anoraks, long drawers, windproof trousers. (see Section VII)

Multiple regression analysis was carried out on the crossing and base data with 'total number of layers' of clothing as the dependent variable and the following as the independent variables:-

(1) Temperature
(2) Wind
(3) Activity
(4) Altitude
(5) Cloud cover
(6) Drift
(7) Wind chill

Wind chill is a function of temperature and wind, and the analysis was carried out both with wind chill as an independent variable (omitting temperature and wind) and with temperature and wind as independent variables. (omitting wind chill)

Similar multiple regression analyses were performed with number of layers on the hands, upper trunk, lower trunk and feet as the dependent variables.

The 'Forward Selection Process' was used to insert the independent variables until the regression equation was satisfactory. (Draper & Smith 1966)

(4) WEIGHT AND FAT THICKNESS

The average 'mean fat thickness' and the average weight of the men was calculated for each month from November 1956 until February 1958. January 1957 and October 1957 were omitted because of lack of data. Several interpolated readings were made to fill in remaining gaps in the data. The readings for the men were not all made on the same day of the month, so the records have been divided into monthly periods, and on occasions when more than one set of data was available, the average reading for the month was taken.

For the period of the crossing, November 24th until March 2nd, five weight records were made at the South Pole and four records were made on arrival at Scott Base. No fat thickness records are available for the crossing.

The aims of the body weight and fat thickness analyses were to discover:-

(a) How body weight and fat thickness changed in a cold environment.

(b) Which skinfold site was best suited to predict body weight and what the relationship was.

The linear regressions of mean fat thickness on temperature and weight on temperature were calculated for each man for the period at base. The linear regressions of weight on mean fat thickness, and weight on fat thickness measured at each of the five sites, were also calculated for each man and for each month.

AVERAGE MONTHLY NUMBER OF LAYERS FOR TWELVE MEN, TEMPERATURE AND WINDCHILL AT SHACKLETON BASE AND FOR THE CROSSING.

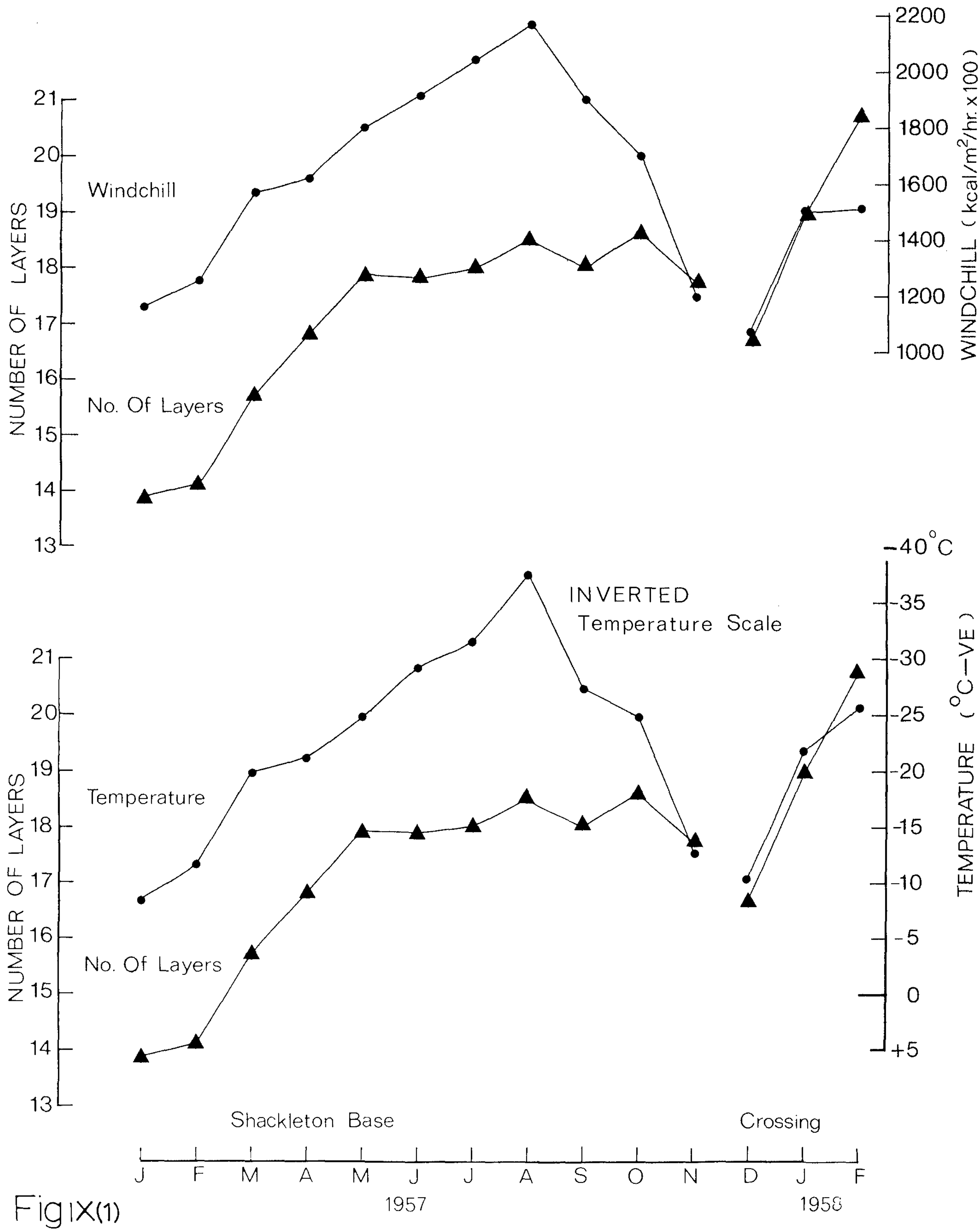


Fig IX(1)

RESULTS

(1) CLOTHING DATA COLLECTED AT BASE

Preliminary Analysis

Figure IX (1) compares the group's average monthly 'total number of layers' with the temperature and wind chill for the period at Shackleton Base. The 'total number of layers' of clothing for the men who spent the winter at South Ice was not included in this average figure. (Note that the temperature scale has been inverted for comparison reasons.) The general impression from the graph is that the 'total number of layers' increased in proportion to the temperature fall, without decreasing the same amount when the temperature rose again.

Figure IX (2) is a graph of average weekly 'total number of layers' against temperature for the men who spent the winter at Shackleton Base. The regression line is given by $y = 13.7 - 0.14t$ (y = average weekly 'total number of layers'; t = temperature ($^{\circ}$C)), the correlation coefficient $r = -0.82$ is significant at the 1% level.

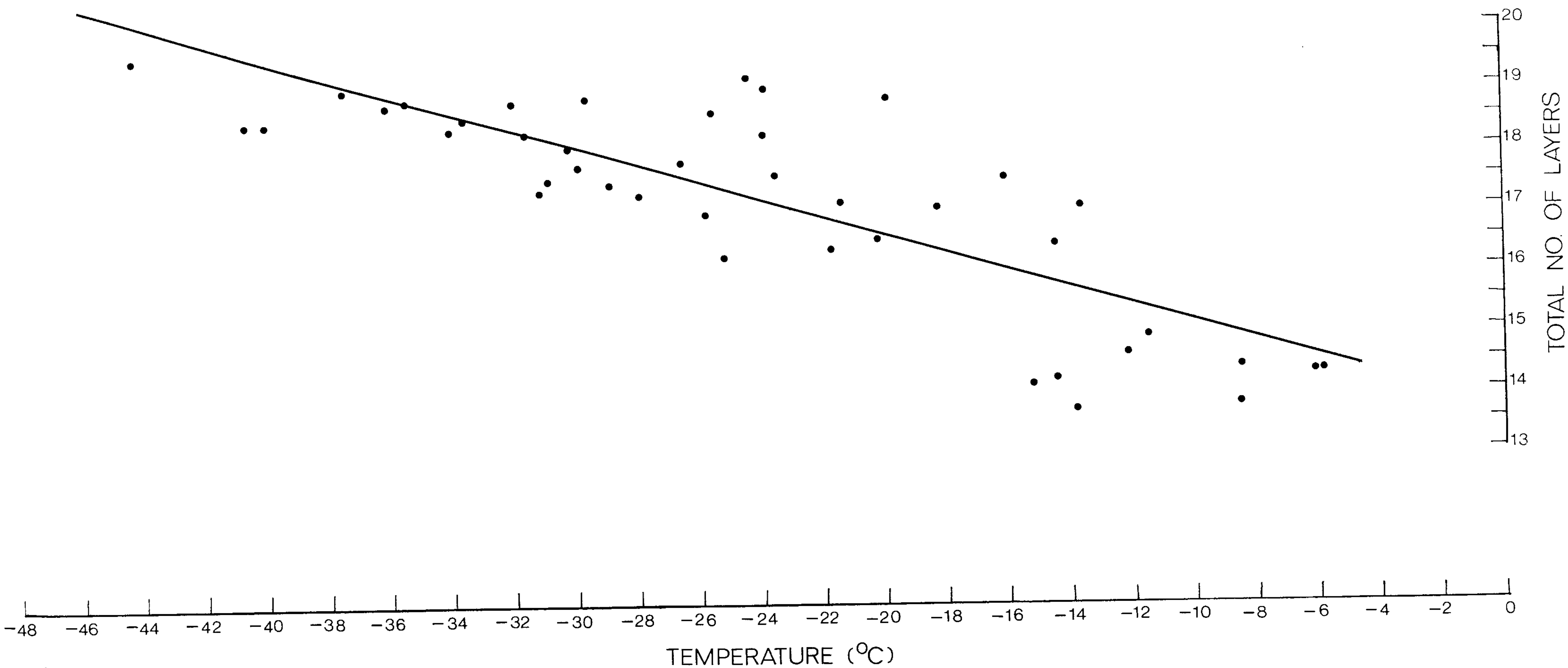
Comparison of Similar Environmental Periods

Below is a list of the temperature ($^{\circ}$C), the windspeed (m/sec and knots), the wind chill (Kcal/m^2/hr) and the average number of hours of sunshine a day from January to November 1957 at Shackleton Base.

Month	Temp. ($^{\circ}$C)	Wind (m/sec)	Wind (knots)	Wind Chill (Kcal/m^2/hr)	Hours of Sunshine (daily average)
January	- 8.2	5.5	10.7	1160	10.1
February	-11.8	5.5	10.7	1250	7.9
March	-19.8	7.1	13.8	1570	3.1
April	-21.1	7.0	13.6	1620	0.8
May	-24.7	9.3	18.1	1800	0.0*
June	-29.3	7.1	13.8	1910	0.0*
July	-31.5	9.3	18.1	2040	0.0*
August	-37.5	8.5	16.5	2170	0.4
September	-27.3	9.3	18.1	1890	0.6
October	-24.7	5.2	10.1	1600	7.2
November	-12.7	4.1	7.9	1200	No record

* The sun was below the horizon from May to July.

WEEKLY AVERAGE TOTAL NUMBER OF LAYERS AGAINST TEMPERATURE FOR PERIOD AT SHACKLETON BASE



FigIX(2)

Two pairs were chosen from the eleven months. April was paired with October and January with November. The two months in each pair had similar conditions of windspeed and temperature and similar wind chill figures. In pair '1' the number of hours of sunshine was greater in October than in April, and in pair '2' there was no sunshine measurement for November. The 'total number of layers' worn during the individual months in each pair were compared.

Pair No.	Months	Total Number of Layers	Wind Chill
1	April	16.5	1620
	October	18.6	1600
2	January	13.9	1160
	November	17.7	1200

In both pairs there was a significant increase ($p \leq 0.01$) in the 'total number of layers' worn during the second month over the first. The greater amount of sunshine in October than in April (pair 1) adds to the significance of the result.

Comparison of Clothing Worn by New Arrivals with that Worn by Members of the Advance Party Staying On at Shackleton Base

The members of the Trans-Antarctic Expedition at Shackleton Base from mid January 1957 onwards can be considered, for a short time at least, as consisting of two groups which might show differences in acclimatization to cold.

Group '1' consisted of those men who had spent the first winter at Shackleton Base under unusually severe conditions as members of the Advance Party. (subjects 1, 2, 3, 4 and 13)

Group '2' consisted of those men who had not spent the first winter at Shackleton Base and who had just arrived in comfort aboard the M.V. Magga Dan. (subjects 5 to 12 and 14 to 16)

The men in group '2' arrived at Shackleton Base on 13th January 1957, and full clothing records are available for them. The base hut was not ready for immediate occupation and men moved ashore for sleeping and living purposes at the rate of one or two a day over the next week. Full clothing records are available for group '1' from 20th January 1957.

The clothing worn by the two groups of men living at the same base under the same conditions was compared week by week for the next six weeks, from 20th January 1957 until 2nd March 1957.

For each week the average 'total number of layers' for each man was calculated. The values for the men in group '1' were then compared with those for the men in group '2'. In none of the six weeks was there found to be a significant difference between the 'total number of layers' worn by men in group '1' and men in group '2'. (t test of difference between two independent samples, Snedecor & Cochran 1967)

Comparison of Clothing Worn at Shackleton Base with that Worn at South Ice.

The men were divided into two groups for the period January to October 1957.

Group '1' Men who spent the second winter at South Ice (three men)

Group '2' Men who spent the second winter at Shackleton Base (nine men)

The four R.A.F. men (subjects 13, 14, 15 and 16) were not included in the groups.

The 'total number of layers' worn by the individual men in the groups was compared. The mean 'total number of layers' for the men in group '1' was 19.2 (S.D. $\pm$ 1.3) and for group '2' was 17.4 (S.D. $\pm$ 1.6). There was a significant differece between the two groups ($p \leq 0.01$) that is the men who spent the winter at South Ice wore significantly more clothing than the

men at Shackleton Base. Comparison of the graphs of temperature and wind at the two bases shows that weather conditions were more severe at South Ice than at Shackleton. (Figure IV (1) and Figure IV (2))

Multiple Regression Analysis of Clothing and Environmental Data

For all the twelve men at base, the correlation between 'total number of layers' and temperature was better than the correlation between 'total number of layers' and wind chill.

Table IX (1) shows the regression equations for the twelve men at base with 'total number of layers' as the independent variable.

The multiple regression with 'total number of layers' as the dependent variable and temperature, wind, activity and drift as the independent variables was calculated for each man. Temperature was a significant factor in all the equations. No other factor was predominantly significant for all the men.

Subject No.	Coefficient of Temperature (a)	Intercept (b)
1	-0.11	15.1
2	-0.04	14.5
3	-0.16	13.5
4	-0.06	16.5
5	-0.17	12.3
6	-0.13	16.6
7	-0.15	13.9
8	-0.10	15.3
9	-0.08	14.6
10	-0.15	14.2
11	-0.17	15.3
12	-0.12	16.3

Where $y = at + b$

y = 'total number of layers' of clothing

t = temperature °C

Table IX (1) Regression of 'Total Number of Layers' on Temperature for the Twelve Men at Base

AVERAGE WEEKLY NUMBER OF LAYERS FOR 12 MEN ON THE CROSSING

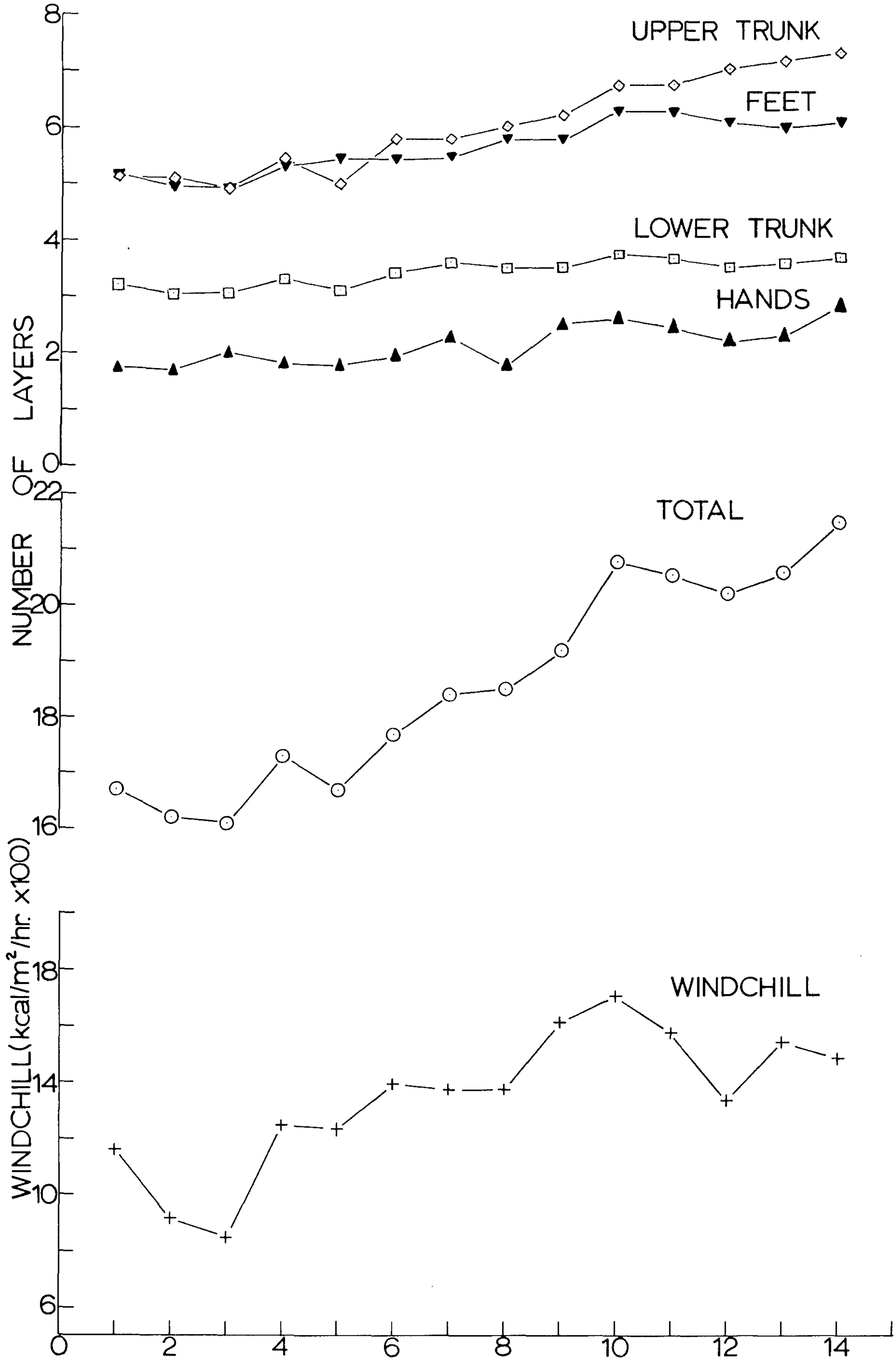


Fig IX(3)

(2) CLOTHING DATA COLLECTED DURING THE CROSSING

Preliminary Analysis

Before using the clothing records to find out whether or not man acclimatizes to cold, it was necessary to establish that the clothing did depend on the temperature.

The figures obtained from all individuals in a given week were averaged and graphs were drawn. These graphs give a general picture of clothing changes for the whole group.

Figure IX (3) shows the average weekly wind chill factor and the average weekly number of layers for the whole group for the period of the crossing. The graph shows that the average weekly 'total number of layers' follows the general trend of the wind chill factor.

The number of layers on the lower trunk and feet follows the wind chill figures better than those for the upper trunk and hands. Even so, the correlation coefficient between wind chill and number of layers of clothing is significant at the 1% level for all four sections of the body, and also for the 'total number of layers'. (including head clothing) For the period of the crossing, the number of layers on the upper trunk increased more than those on any part of the body.

Table IX (2) gives the average number of layers for the whole period of the crossing on each section of the body for each man. The average 'total number of layers' ranges from 16.4 to 20.8.

Figure IX (4) compares the average weekly 'total number of layers' with temperature and the average weekly 'total number of layers' with wind chill. The temperature scale has been inverted for comparison purposes. During the last week of the crossing, clothing records are not available due to the absence of six members of the party, so that the last value shown in Figure IX (4) for the 'total

COMPARISON OF AVERAGE TOTAL NUMBER OF LAYERS WITH TEMPERATURE AND WINDCHILL FOR 12 MEN FOR THE PERIOD OF THE CROSSING

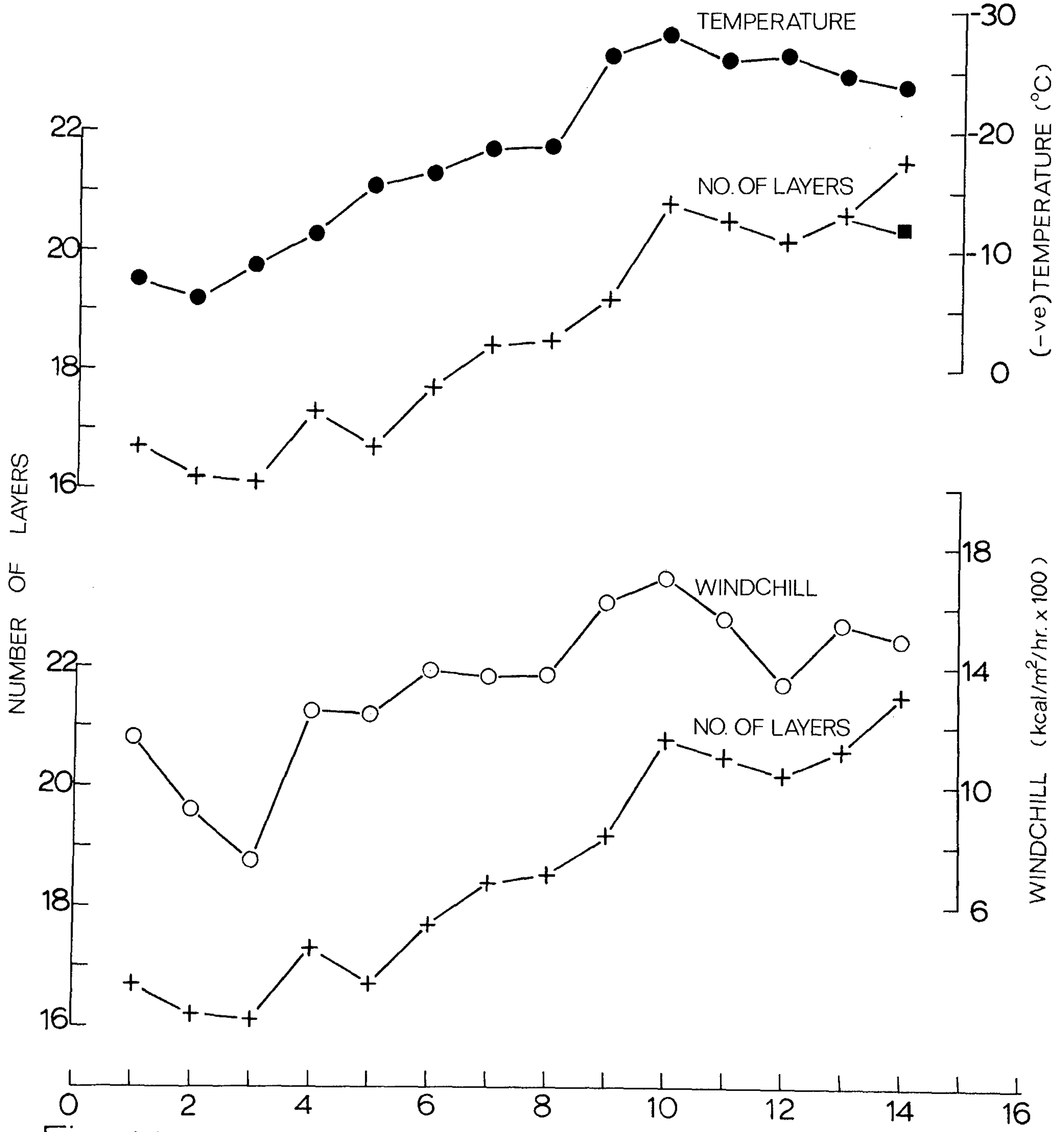


Fig IX(4)

Subject No.	Average Total Number of Layers	Average Number of Layers On			
		Upper Trunk	Lower Trunk	Hands	Feet
1	19.7(±1.5)*	6.6(±1.4)	3.2(±0.5)	3.0(±0.4)	5.9(±0.4)
2	17.7(±2.3)	5.5(±0.7)	3.4(±0.7)	1.7(±0.8)	5.9(±1.0)
3	18.9(±2.2)	6.0(±1.4)	3.6(±0.7)	1.8(±0.7)	6.2(±0.5)
4	19.7(±2.7)	6.0(±0.9)	3.6(±0.6)	2.3(±0.5)	5.9(±1.0)
5	17.4(±2.8)	6.3(±1.1)	3.0(±0.3)	2.1(±0.5)	5.0(±1.6)
6	20.0(±3.0)	6.1(±1.0)	3.9(±0.5)	2.3(±0.5)	5.8(±1.4)
7	17.2(±1.8)	5.8(±0.8)	3.0(±0.2)	1.9(±1.0)	5.6(±0.8)
8	18.8(±2.5)	6.1(±0.7)	3.7(±0.4)	1.8(±0.4)	5.8(±0.9)
9	17.5(±2.3)	5.8(±0.9)	3.1(±0.5)	1.8(±0.8)	5.6(±1.0)
10	18.5(±2.0)	5.9(±0.7)	3.7(±0.4)	2.2(±0.4)	5.7(±0.9)
11	20.8(±4.0)	6.8(±1.7)	3.0(0.0)	3.3(±1.1)	5.3(±1.1)
12	16.4(±2.8)	5.8(±1.0)	2.8(±0.5)	1.4(±0.6)	5.4(±1.4)

* The figures in brackets refer to the standard deviation of the average number of layers.

Table IX (2) Average Number of Layers of Clothing for the Whole Period of the Crossing

GRAPH OF AVERAGE TOTAL NUMBER OF LAYERS AGAINST TEMPERATURE FOR PERIOD OF CROSSING 24.11.57 TO 1.3.58

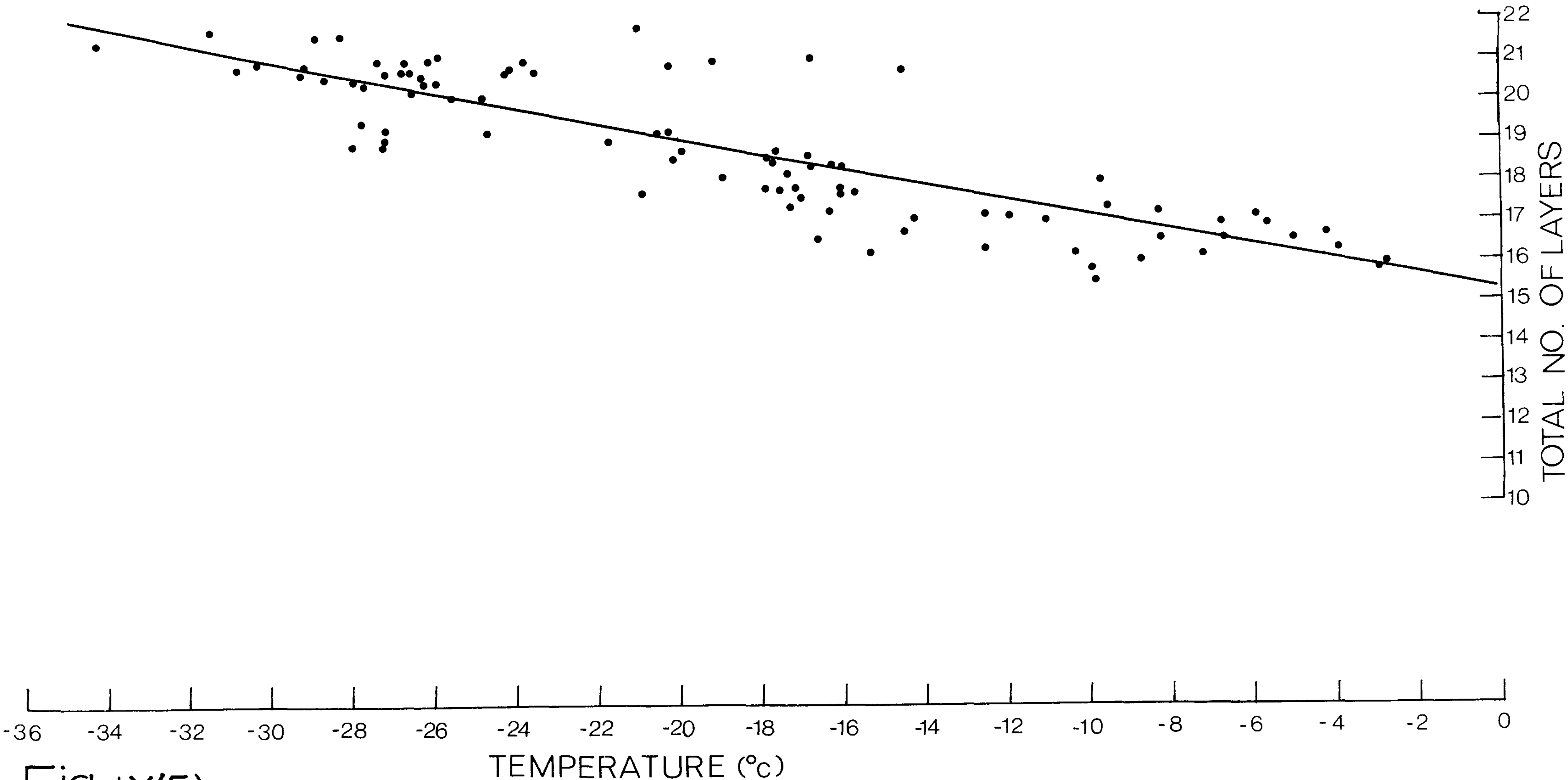


Fig IX(5)

number of layers' is obtained from the other six members only, and is high for this reason. By use of the regression equations, dealt with in detail in a later section, the number of layers of clothing which the other six members could be expected to have worn was calculated and the revised value added to the graph (shown by a different symbol: a black square) The correlation coefficient between the average weekly 'total number of layers' and temperature ($r = -0.92$) is better than the correlation between the average weekly 'total number of layers' and wind chill ($r = 0.84$)

Figure IX (5) is a graph of average daily 'total number of layers' against temperature. The points which deviate most from the line represent days at the end of the crossing. The regression of average daily 'total number of layers' against temperature is given by $y = 15.2 - 0.18t$ (y = average daily 'total number of layers', t = temperature °C) With the increased number of degrees of freedom obtained by taking the average daily value instead of the average weekly value, the correlation coefficient ($r = -0.77$) is still significant at the 1% level. The regression of average daily 'total number of layers' on wind chill for the same period gives a lower correlation coefficient of 0.52.

Comparison of Similar Environmental Periods

Comparison of Similar Weeks During the Crossing

The following Table is a list of the temperature (°C) the windspeed (m/sec and knots), the wind chill (Kcal/m²/hr) and the cloud cover for the fourteen weeks of the crossing.

(N.B. For any week the wind chill is not the figure obtained from the average temperature and the average wind, but that obtained by averaging the wind chill values computed from the temperature and wind for each individual day of the week. These two figures are not the same.) (Court 1948)

Week No.	Temp. (^{o}C)	Wind (m/sec)	Wind (knots)	Wind Chill ($Kcal/m^2/hr$)	Cloud Cover
1	- 7.4	6.6	12.8	1160	5.2
2	- 6.1	3.5	6.8	915	5.6
3	- 8.8	2.6	5.1	847	2.7
4	-11.3	5.7	11.1	1250	7.4
5	-15.4	4.3	8.4	1237	1.4
6	-16.7	5.2	10.1	1393	2.1
7	-18.3	6.2	12.0	1371	3.6
8	-18.9	4.4	8.5	1375	5.2
9	-26.3	5.2	9.9	1615	2.5
10	-28.2	5.4	10.5	1707	5.1
11	-26.0	4.7	9.1	1576	3.6
12	-26.4	2.9	5.6	1337	5.0
13	-24.7	5.6	10.9	1544	7.1
14	-23.8	5.6	10.9	1489	4.7
15					

In order to allow time for possible acclimatization to take place and be reflected in a change in clothing worn, the pairs of weeks should be as far apart in time as possible, ideally one from the beginning and another from the end of the crossing period in each case.

It was difficult to find two weeks with similar weather conditions for comparison purposes, but three pairs were chosen. Pair '1' was week 1 with week 4; pair '2' was week 6 with week 12 and pair '3' was week 8 with week 12. The two weeks comprising each pair have similar wind chill figures, although the temperature and wind is not exactly the same in each week. The cloud cover figures are also not the same in each pair, although in the third pair there is only a difference of 0.2 in the cloud cover figures.

Pair No.	Weeks	Wind Chill ($Kcal/m^2/hr$)	Number of Layers On				Total No. of Layers
			Upper Trunk	Lower Trunk	Feet	Hands	
1	Week 1	1160	5.1	3.2	5.2	1.7	16.7
	Week 4	1250	5.4	3.3	5.3	1.8	17.3
2	Week 6	1393	5.8	3.4	5.5	2.0	17.7
	Week 12	1337	7.0	3.5	6.1	2.2	20.2
3	Week 8	1375	6.0	3.5	5.9	1.8	18.5
	Week 12	1337	7.0	3.5	6.1	2.2	20.2

The above table gives the number of layers and wind chill values for respective pairs of weeks

In each case the number of layers of clothing is the average for the whole group for that week.

In pair number '1' there was no significant change in the clothing worn from week 1 to week 4.

In pair number '2' there was a significant increase from week 6 to week 12 in the layers worn on the upper trunk, and in the 'total number of layers.' ($p \leq 0.01$) There was no significant change in the number of layers worn on the lower trunk, feet or the hands.

Exactly the same observation is true for pair number '3'.

GRAPH OF AVERAGE TOTAL NUMBER OF LAYERS AGAINST NUMBER OF DAYS FROM THE START OF THE CROSSING FOR DAYS IN 7 WINDCHILL RANGES

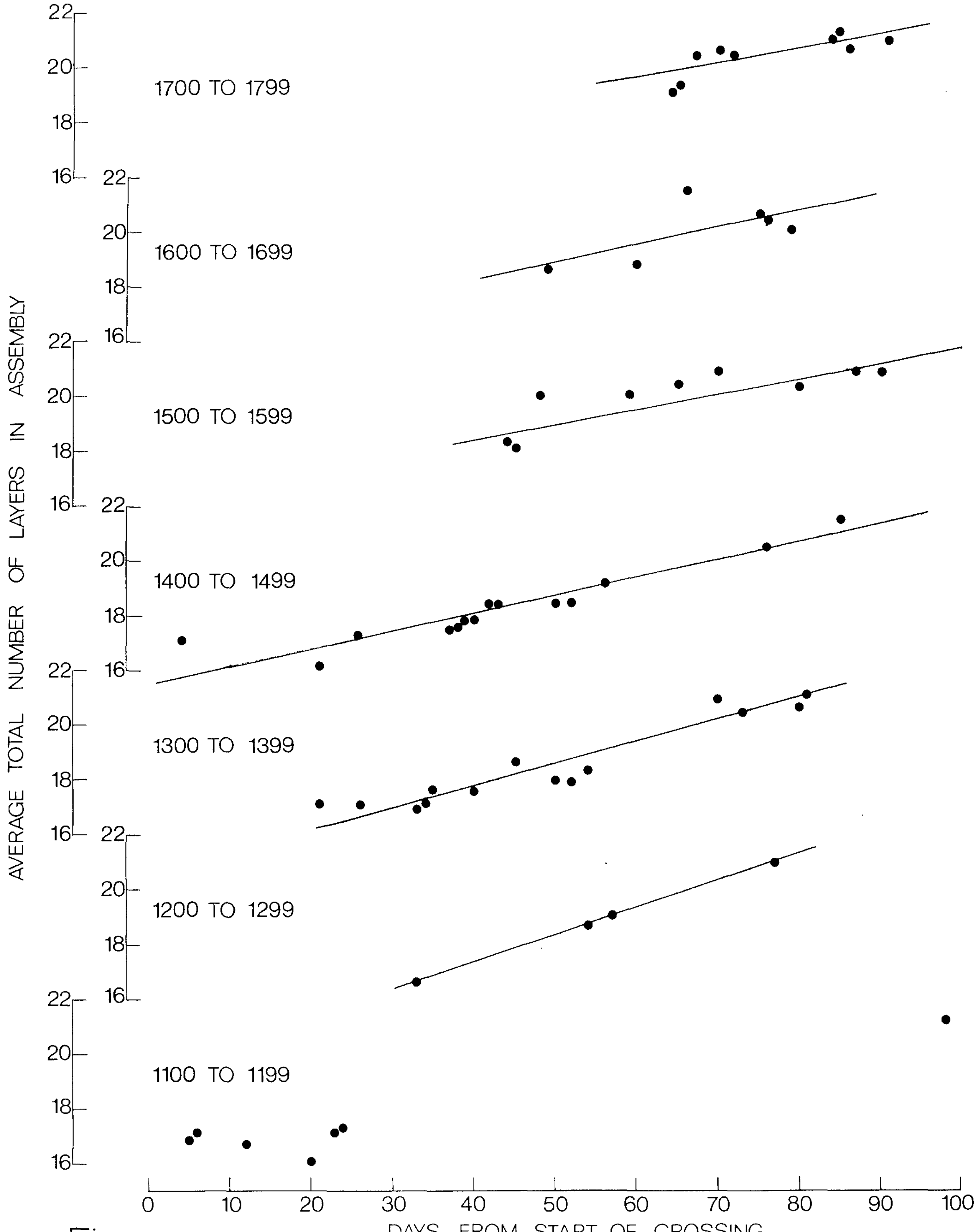


Fig IX(6)

Comparison of Similar Days During the Crossing

The days were allotted to seven groups according to the wind chill figure for the day.

	Wind Chill in Ranges:-	No. of Days in Group
Group W1	1100 to 1199	7
Group W2	1200 to 1299	4
Group W3	1300 to 1399	14
Group W4	1400 to 1499	14
Group W5	1500 to 1599	9
Group W6	1600 to 1699	6
Group W7	1700 to 1799	9

Days with wind chill below 1100 and above 1800 were not included. The days were also divided into six groups according to the temperature for the day.

	Temperature in Ranges:-	No. of Days in Group
Group T_1	$-13^{\circ}C$ to $-15.9^{\circ}C$	5
Group T_2	$-16^{\circ}C$ to $-18.9^{\circ}C$	18
Group T_3	$-19^{\circ}C$ to $-21.9^{\circ}C$	8
Group T_4	$-22^{\circ}C$ to $-24.9^{\circ}C$	8
Group T_5	$-25^{\circ}C$ to $-27.9^{\circ}C$	18
Group T_6	$-28^{\circ}C$ to $-30.9^{\circ}C$	7

Days with temperature above $-16^{\circ}C$ and below $-30.9^{\circ}C$ were omitted. The 'total number of layers' worn by each man on days of similar wind chill were then compared, and likewise the clothing worn on days of similar temperature, looking, of course, for a decreased clothing requirement with the passage of time as evidence of acclimatization to cold.

Wind chill group W3 and temperature group T_4 both contain days spaced well apart over the whole period of the crossing,

GRAPH OF AVERAGE TOTAL NUMBER OF LAYERS AGAINST NUMBER OF DAYS FROM THE START OF THE CROSSING FOR DAYS IN 6 TEMPERATURE RANGES

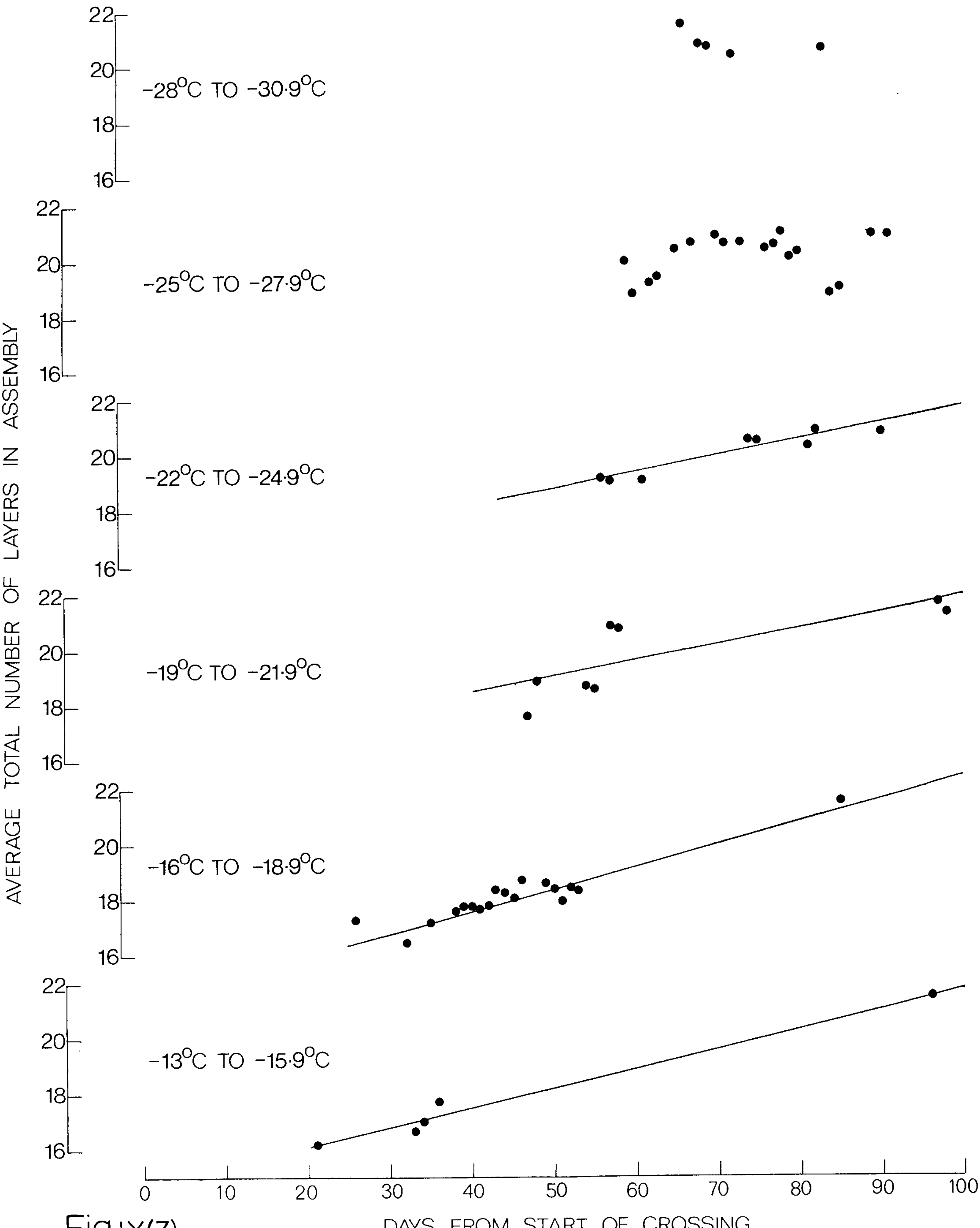


Fig IX(7)

and have therefore been tabulated. All the groups are also shown in graphic form. (Figures IX (6) and IX (7))

Table IX (3) gives the 'total number of layers' worn by all the men on the days in wind chill group W3. Subject number 12 is missing because of incomplete records. Of the remaining eleven subjects, ten have increased the 'total number of layers' worn from the first day to the last day in the group.

Table IX (4) gives the 'total number of layers' worn by all the men on the days in temperature group T_4. Subject number 12 is again missing because of incomplete data. In this case, eight out of eleven men have increased the 'total number of layers' worn from the first day to the last day in the group; two have remained the same, and there is a decrease of one layer in one subject only.

The graphs in Figure IX (6) show the 'total number of layers' worn against time for each wind chill group, and in each case there is an increase. The coefficient of correlation between the 'total number of layers' and the elapsed time is significant at the 1% level for each group.

The graphs for the temperature groups T_1 to T_4, (Figure IX (7)) similarly show an increase in the 'total number of layers' of clothing worn with time, again significant at the 1% level. The graphs for temperature groups T_5 and T_6 show no significant increase in the number of layers of clothing worn. These were the lowest temperature groups, and in all cases the subjects were already wearing the maximum amount of clothing that they ever wore. They did not wear less clothing under similar weather conditions with the passage of time.

Subject No.	Day Number													
	21	26	33	34	35	40	45	50	52	54	70	73	80	81
1	–	–	16	16	18	19	20	19	20	21	21	20	21	21
2	18	18	16	16	16	16	18	17	17	17	21	20	21	21
3	17	19	18	18	18	17	18	14	14	15	19	21	18	18
4	18	19	18	18	19	19	21	19	19	20	23	23	23	23
5	16	14	16	16	16	16	17	17	17	17	23	20	–	–
6	18	18	18	20	20	20	21	21	21	21	23	23	23	23
7	18	18	16	16	18	18	18	18	18	18	16	16	18	18
8	17	17	–	–	18	18	19	19	19	19	21	21	22	22
9	16	15	17	17	17	17	18	16	16	16	22	21	19	19
10	16	16	18	18	18	18	18	19	19	19	23	21	21	21
11	–	–	17	17	17	16	17	19	19	19	19	19	25	25

Table IX (3) Total Number of Layers Worn by Each Man for Days when the Wind Chill was in the Range of 1300 to 1399

Subject No.	Day Number							
	56	57	61	74	75	81	82	90
1	21	20	20	20	20	21	21	21
2	17	19	18	20	21	19	19	20
3	22	19	20	21	21	18	18	22
4	21	17	17	23	23	23	23	22
5	17	17	17	20	20	15	–	16
6	22	21	21	21	23	23	23	–
7	18	16	17	16	16	18	18	19
8	19	–	–	21	21	22	22	22
9	16	17	17	21	21	19	19	20
10	19	19	18	21	21	21	21	21
11	19	26	26	19	19	25	25	25

Table IX (4) Total Number of Layers Worn by Each Man for Days when Temperature was in the Range of $-22^{\circ}C$ to $-24.9^{\circ}C$.

The Merits of Temperature as an Independent Variable over that of Wind Chill

As wind chill is a function of temperature and wind, (Figure VI (3)) the multiple regression with 'total number of layers' as the dependent variable and temperature and wind as the independent variables, was compared with the regression of 'total number of layers' on wind chill alone. For all the twelve men on the crossing, the variables temperature and wind taken together, gave a better correlation than wind chill. However, temperature and wind taken together did not give a significantly better correlation than temperature alone. Table IX (5) compares the correlation coefficient for all the three regressions. The correlation between number of layers and temperature was also better than that between number of layers and wind chill for all the other sections of the body.

It appears that temperature gave a better indication than wind chill of the outside weather conditions, as judged by the clothing worn. This could be because the men wore highly windproof clothing, and on the crossing they were often protected from the wind by the vehicles.

Table IX (6) shows the regression equations for the twelve men on the crossing with 'total number of layers' as the dependent variable, and temperature as the independent variable.

Analysis of Variance

Before undertaking the major computation involved in a multiple regression analysis of such a large volume of data, a preliminary examination was made to test the existence of differences justifying such analysis.

A "Two Factor Analysis of Variance' was performed on the 'total number of layers' of clothing for the period of the crossing, to investigate whether or not a difference

Subject No.	r_1	r_2	r_3	n
1	0.39	0.39	0.14	65
2	0.54	0.55	0.48	83
3	0.6	0.6	0.41	110
4	0.48	0.49	0.43	83
5	0.58	0.58	0.25	77
6	0.74	0.76	0.66	76
7	0.57	0.59	0.43	110
8	0.81	0.81	0.49	101
9	0.66	0.66	0.47	96
10	0.78	0.79	0.46	89
11	0.7	0.7	0.42	83
12	0.41	0.49	0.64	38

r_1 = Correlation coefficient between 'total number of layers' and temperature.

r_2 = Multiple correlation coefficient with 'total number of layers' as dependent variable and temperature and wind as independent variables.

r_3 = Correlation coefficient between 'total number of layers' and wind chill.

n = Number of paired sets of data used.

(N.B. the signs of the correlation coefficients have been ignored)

Table IX (5) Correlation Coefficients Between Total Number of Layers and Temperature; Total Number of Layers and Wind and Temperature Taken Together and Total Number of Layers and Wind Chill.

Subject No.	Coefficient of Temperature (a)	Intercept (b)
1	-0.06	19.6
2	-0.15	16.2
3	-0.17	16.3
4	-0.20	17.3
5	-0.27	12.8
6	-0.28	20.7
7	-0.16	15.0
8	-0.29	14.3
9	-0.20	18.5
10	-0.21	15.9
11	-0.34	15.5
12	-0.21	15.0

Where $y = at + b$

y = 'total number of layers' of clothing

t = temperature °C

Table IX (6) Regression of 'Total Number of Layers' on Temperature for the Twelve Men on the Crossing

between subjects and a difference between days existed. It was found that a significant difference in the clothing worn 'between the subjects' existed, ($p \leq 0.01$) and also a significant difference in the clothing worn 'between the days'. ($p \leq 0.01$) The 'between days' difference and the 'between subjects' difference were both analysed in more detail, and the results of these further analyses are in the following Sections.

Differences in Clothing Worn by the Men During the Crossing

Table IX (7) gives the average value of the 'total number of layers' worn by each man for the whole period of the crossing, ranked in ascending order. It also gives average values of the weights, heights, surface areas and mean fat thicknesses of the twelve men. There is no obvious relationship between the average 'total number of layers' and any of the other four variables.

The subject with the highest average 'mean fat thickness' has a relatively large value for the average 'total number of layers', and the subject with the lowest 'mean fat thickness' has a relatively low value for the average 'total number of layers.' This data shows no evidence that fatter men need less clothing. The multiple regression analysis with average 'total number of layers' as the dependent variable and age, weight, mean fat thickness, surface area and height as the independent variables, was also not significant for any of the combinations of independent variables which were tried.

The weather conditions were divided into three categories; medium, medium severe and severe, and a typical day picked out from each section.

For the medium conditions, the regression of 'total number of layers' on weight, and the regression of 'total number of layers' on surface area were significant at the 5% level. No other combination of independent variables

Subject No.	Average Total No. of Layers	Average Mean Fat Thickness	Average Weight	Height	Average Surface Area
12	16.4	12.2	78.8	187.3	2.05
7	17.2	5.6	66.7	171.7	1.79
5	17.4	16.6	76.8	172.7	1.90
9	17.5	12.4	85.4	186.6	2.11
2	17.7	17.9	80.2	172.1	1.93
10	18.5	14.3	75.4	177.8	1.93
8	18.8	6.9	67.5	179.1	1.85
3	18.9	5.6	66.7	171.7	1.79
4	19.7	6.9	67.5	179.1	1.85
1	19.7	18.4	90.5	184.2	2.14
6	20.0	10.2	74.9	182.9	1.96
11	20.8	10.5	75.1	175.3	1.91

Table IX (7) Average 'Total Number of Layers,' Mean Fat Thickness, Weight, Height and Surface Area of Twelve Subjects for the Period of the Crossing.

gave a better regression equation.

For the medium severe conditions, the regression with 'total number of layers' as the dependent variable and fat thickness, height and weight as independent variables was significant at the 5% level.

For the severe conditions, the regression of 'total number of layers' on activity was significant at the 5% level.

However, the analysis has only been performed for one day out of each of the different sections, so it is difficult to draw any definate conclusions from these results.

<u>Multiple Regression Anslysis of Clothing and Environmental Data</u>

The relative importance of the independent variables in the multiple regression analysis for each individual man was calculated using the 'Forward Selection Procedure.' The following independent variables were used in the analysis:-

(1) Temperature

(2) Wind

(3) Altitude

(4) Activity

(5) Cloud Cover

(6) Drift

Tables IX (8) to IX (12) give the significance of the independent variables when:-

(1) 'Total number of layers' is taken as the dependent variable

(2) Number of layers on the upper trunk is taken as the dependent variable

(3) Number of layers on the lower trunk is taken as the dependent variable

(4) Number of layers on the hands is taken as the dependent variable

(5) Number of layers on the feet is taken as the dependent variable

Table IX (8) shows that when 'total number of layers' was taken as the dependent variable, significant regression equations were calculated for eleven out of the twelve men. For these eleven men, temperature was a significant variable in all the equations, and cloud cover was a significant variable in nine out of the eleven equations. Activity was significant in six out of the eleven equations, but the sign of the activity coefficient was positive in all six cases. This casts some doubt on the validity of the activity data because one would expect 'total number of layers' to decrease as activity increased.

Table IX (9) shows that when the number of layers on the upper trunk was taken as the dependent variable, all twelve regression equations were significant. Again temperature and cloud cover were significant in the majority of equations.

When the number of layers on the lower trunk was taken as the dependent variable, ten out of the twelve regression equations were significant. In these ten equations, temperature was significant in eight of them, altitude was significant in six, activity was significant in seven and cloud cover was significant in five. (Table IX (10))

Subject No.	Temperature	Wind	Altitude	Activity	Cloud Cover	Drift
1	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.
2	S.** (-ve)	N.S.	N.S.	S.** (+ve)	S.** (+ve)	N.S.
3	S.** (-ve)	N.S.	S.** (-ve)	N.S.	S.** (+ve)	N.S.
4	S.** (-ve)	S.** (+ve)	N.S.	S.** (+ve)	S.** (+ve)	S.** (-ve)
5	S.** (-ve)	N.S.	S.** (-ve)	N.S.	N.S.	N.S.
6	S.** (-ve)	S.* (+ve)	N.S.	S.** (+ve)	S.** (+ve)	N.S.
7	S.** (-ve)	S.** (+ve)	N.S.	N.S.	S.** (+ve)	N.S.
8	S.** (-ve)	S.* (-ve)	N.S.	S.** (+ve)	S.** (+ve)	S.** (+ve)
9	S.** (-ve)	N.S.	N.S.	S.** (+ve)	S.** (+ve)	N.S.
10	S.** (-ve)	N.S.	N.S.	N.S.	N.S.	N.S.
11	S.** (-ve)	N.S.	S.** (-ve)	N.S.	S.** (+ve)	S.* (+ve)
12	S.** (-ve)	S.* (+ve)	N.S.	S.** (+ve)	S.** (+ve)	N.S.

N.S. = Not significant

S. = Significant (+ve or -ve indicates the sign of the regression)

* = Significant at 5% level

** = Significant at 1% level

Table IX (8) Significance of the Independent Variables in the Multiple Regression Analysis with 'Total Number of Layers' as the Dependent Variable

Subject No.	Temperature	Wind	Altitude	Activity	Cloud Cover	Drift
1	S.** (-ve)	N.S.	S.** (-ve)	N.S.	S.* (+ve)	N.S.
2	S.* (-ve)	N.S.	N.S.	S.** (+ve)	S.** (+ve)	N.S.
3	S.** (-ve)	N.S.	N.S.	N.S.	S.** (+ve)	N.S.
4	S.** (-ve)	N.S.	N.S.	S.** (+ve)	S.** (+ve)	S.* (-ve)
5	S.** (-ve)	S.** (+ve)	S.** (-ve)	N.S.	S.** (+ve)	N.S.
6	S.** (-ve)	S.** (+ve)	N.S.	S.** (+ve)	S.** (+ve)	S.* (-ve)
7	S.** (-ve)	N.S.	S.* (-ve)	N.S.	S.** (+ve)	N.S.
8	S.** (-ve)	N.S.	S.** (+ve)	N.S.	S.** (+ve)	N.S.
9	S.** (-ve)	N.S.	N.S.	S.** (+ve)	N.S.	N.S.
10	S.** (-ve)	N.S.	N.S.	N.S.	N.S.	S.* (+ve)
11	S.** (-ve)	N.S.	N.S.	N.S.	S.* (+ve)	S.* (+ve)
12	S.** (-ve)	S.** (+ve)	S.** (-ve)	S.** (+ve)	S.** (+ve)	N.S.

N.S. = Not significant

S. = Significant (+ve or -ve indicates the sign of regression)

* = Significant at 5% level

** = Significant at 1% level

Table IX (9) Significance of the Independent Variables in the Multiple Regression Analysis with 'Number of Layers on the Upper Trunk' as the Dependent Variable

Subject No.	Temperature	Wind	Altitude	Activity	Cloud Cover	Drift
1	S.** (+ve)	N.S.	S.** (+ve)	S.** (+ve)	N.S.	S.** (+ve)
2	S.** (-ve)	N.S.	S.** (+ve)	S.** (+ve)	S.** (+ve)	N.S.
3	S.** (-ve)	N.S.	S.** (-ve)	N.S.	S.** (+ve)	N.S.
4	S.** (-ve)	S.** (+ve)	N.S.	N.S.	S.** (+ve)	S.** (-ve)
5	S.** (-ve)	N.S.	N.S.	S.** (+ve)	N.S.	N.S.
6	N.S.	N.S.	N.S.	S.** (+ve)	N.S.	N.S.
7	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.
8	S.** (-ve)	S.** (+ve)	S.** (+ve)	N.S.	N.S.	S.** (+ve)
9	S.** (-ve)	N.S.	S.** (-ve)	S.** (+ve)	N.S.	N.S.
10	N.S.	N.S.	S.** (+ve)	S.** (-ve)	S.** (-ve)	S.** (+ve)
11	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.
12	S.** (-ve)	S.** (+ve)	N.S.	S.** (+ve)	S.** (+ve)	

N.S. = Not significant

S. = Significant (+ve or -ve i dicates the sign of regression)

* = Significant at 5% level

** = Significant at 1% level

Table IX (10) <u>Significance of the Independent Variables in the Multiple Regression Analysis with 'Number of Layers on the Lower Trunk' as the Dependent Variable</u>

Subject No.	Temperature	Wind	Altitude	Activity	Cloud Cover	Drift
1	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.
2	S.** (-ve)	N.S.	S.** (-ve)	S.** (+ve)	S.** (+ve)	N.S.
3	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.
4	S.** (-ve)	N.S.	N.S.	S.** (+ve)	N.S.	N.S.
5	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.
6	S.** (-ve)	N.S.	S.* (-ve)	S.** (+ve)	S.** (+ve)	N.S.
7	S.** (-ve)	N.S.	N.S.	N.S.	N.S.	S.* (+ve)
8	S.** (-ve)	N.S.	S.** (+ve)	N.S.	N.S.	N.S.
9	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.
10	S.** (-ve)	N.S.	N.S.	N.S.	N.S.	N.S.
11	S.** (-ve)	N.S.	S.** (-ve)	N.S.	N.S.	N.S.
12	N.S.	N.S.	N.S.	S.* (+ve)	N.S.	N.S.

N.S. = Not significant

S. = Significant (+ve or -ve indicate the sign of regression)

* = Significant at 5% level

** = Significant at 1% level

Table IX (11) <u>Significance of the Independent Variables in the Multiple Regression Analysis with 'Number of Layers on the Hands' as the Dependent Variable</u>

Subject No.	Temperature	Wind	Altitude	Activity	Cloud Cover	Drift
1	N.S.	N.S.	N.S.	S.** (+ve)	N.S.	N.S.
2	S.** (-ve)	S.** (+ve)	N.S.	N.S.	S.** (+ve)	S.** (-ve)
3	S.** (-ve)	N.S.	S.** (-ve)	N.S.	S.** (+ve)	S.** (-ve)
4	S.** (-ve)	N.S.	N.S.	S.* (+ve)	S.** (+ve)	N.S.
5	S.** (-ve)	N.S.	S.* (-ve)	N.S.	N.S.	N.S.
6	N.S.	N.S.	S.** (+ve)	S.** (+ve)	N.S.	N.S.
7	S.** (-ve)	S.* (+ve)	N.S.	N.S.	N.S.	S.** (-ve)
8	S.** (-ve)	N.S.	N.S.	N.S.	S.** (+ve)	S.** (+ve)
9	S.** (-ve)	N.S.	N.S.	S.** (+ve)	S.** (+ve)	N.S.
10	S.** (-ve)	N.S.	N.S.	N.S.	N.S.	N.S.
11	S.** (-ve)	N.S.	N.S.	N.S.	S.** (+ve)	N.S.
12	S.** (-ve)	N.S.	N.S.	S.* (+ve)	N.S.	S.* (-ve)

N.S. = Not significant

S. = Significant (+ve or -ve indicates the sign of regression

* = Significant at 5% level

** = Significant at 1% level

Table IX (12) Significance of the Independent Variables in the Multiple Regression Analysis with 'Number of Layers on the Feet' as the Dependent Variable

When the number of layers on the hands was taken as the dependent variable, only eight out of the twelve equations were significant. When the number of layers on the feet was taken as the dependent variable, all twelve equations were significant, and in this case, drift was significant in five out of the twelve equations, which is a higher proportion than in any of the other cases. (Tables IX (11) and IX (12))

(3) COMPARISON OF CLOTHING WORN AT BASE WITH THAT WORN DURING THE CROSSING

Figure IX (1) shows the average monthly 'total number of layers' worn at Shackleton Base and on the crossing. For the whole three months of the crossing, the average monthly 'total number of layers' was greater than that at base for months with similar temperatures and wind chill.

The number of layers of clothing worn at Shackleton increased with time, and was higher for example in November than in January, even when the outside weather conditions were similar. The same increase in the number of layers of clothing worn with time was evident on the crossing.

The regression equation of average <u>weekly</u> 'total number of layers' against temperature for the crossing is:-

$$y = 14.5 - 0.22t$$

The regression equation of average <u>weekly</u> 'total number of layers' for the period at Shackleton Base is:-

$$y = 13.7 - 0.14t$$

(y = average weekly 'total number of layers'; t = temperature $^{\circ}C$.)

This shows that on the crossing the clothing worn by the men was more dependent on temperature than it was at base, and that they wore more clothing on the crossing than they did at base under similar temperature conditions.

AVERAGE MONTHLY TEMPERATURE, BODY WEIGHT AND MEAN FAT THICKNESS FOR 10 MEN ON THE TRANS-ANTARCTIC EXPEDITION.

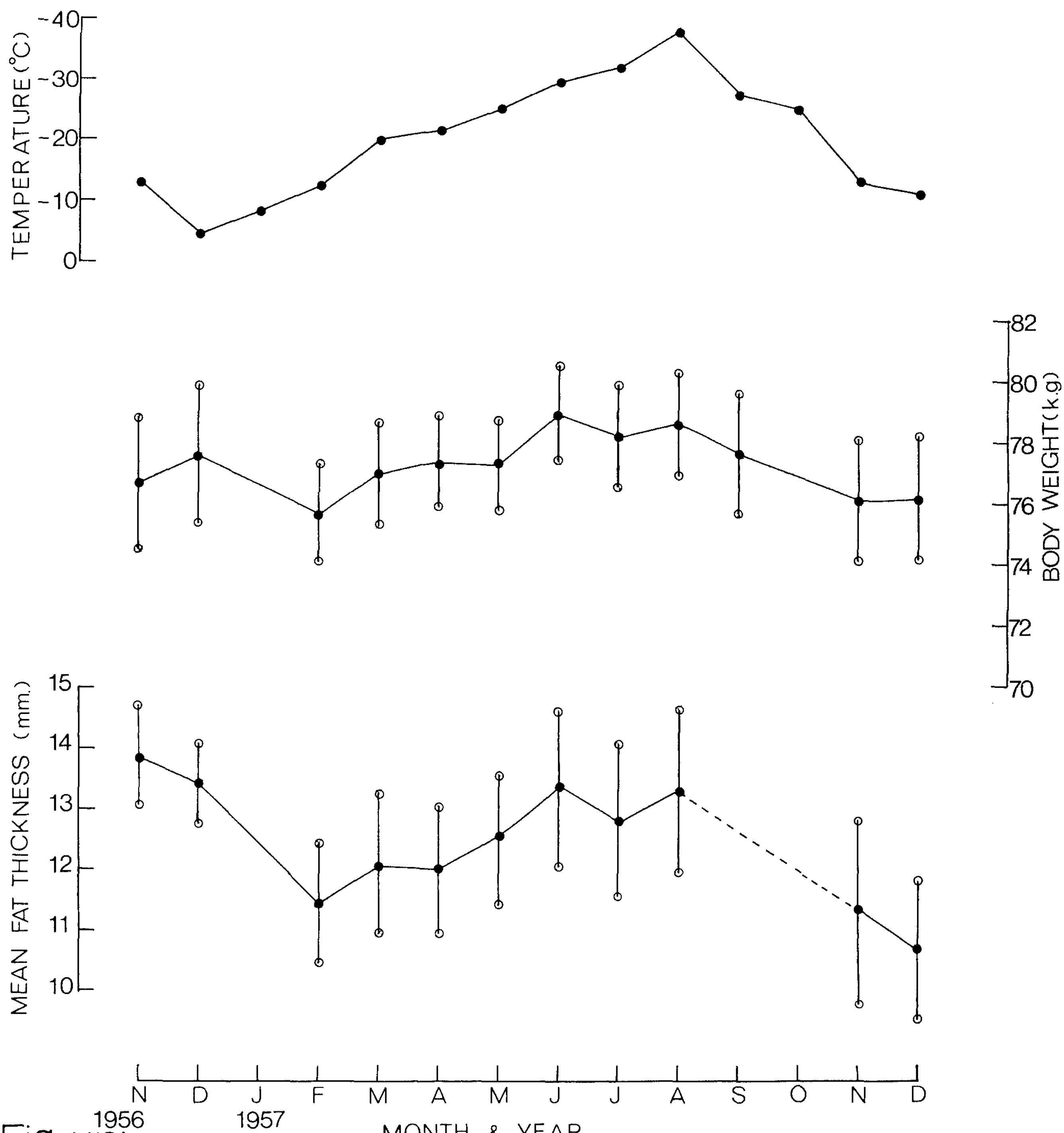


Fig IX(8)

Table IV gives the average value of the mean fat thickness and the average value of the weight for the period November 1956 until February 1958, for each of the sixteen men on the expedition. The average weight for all the sixteen men was 79.8 Kgms, (S.D. $\pm$ 7.8) and the average mean fat thickness for all sixteen men was 13.1. (S.D. $\pm$ 4.0)

When comparing body weight with skinfold thickness, Lewis, Masterton and Rosenbaum (1960) adjusted the weight of their men to a standard height of 177 cm, and to a standard age of 33 years. In the present study, taking data from Table IV (2) the correlation between weight and age is not significant, although the correlation between weight and height is significant at the 5% level. In this study, weight was adjusted to a standard height of 177 cm by a correction of 0.68 Kg/cm and no adjustment was made for age. (Rosenbaum 1951) This adjustment was made to correct for bias due to height when comparing the weight with the mean fat thickness of the twelve men.

Figure IX (8) shows the monthly average corrected weight, and the monthly average mean fat thickness of the ten men for the period November 1956 until December 1957. It also shows the temperature for this period and the temperature scale has been inverted for comparison purposes. The intervals of weight and mean fat thickness for each month are the 95% confidence intervals. The values for December 1956 and January, September and October 1957 are missing because of insufficient data.

Seasonal Fluctuations in Weight and Fat Thickness

The average mean fat thickness initially decreased and then increased in the colder months from July to August. In November and December, the average mean fat thickness decreased again from the August value. The correlation between average mean fat thickness and temperature was not significant.

The average weight appears to vary with temperature and the correlation between weight and temperature is significant at the 1% level.

The average weight of the ten men was 3.4 Kg less in December 1957 than in December 1956. The average mean fat thickness decreased by 6.2mm during the same period. There was no restriction on food intake at base and the usual caloric intake was between 4,000 Kcal and 4,500 Kcal a day.

Relationship Between Weight and Fat Thickness

Considering the individual records for each subject for each month, the correlation between corrected weight and mean fat thickness was significant at the 1% level for eight out of the ten men. The two men whose weight was not correlated with their mean fat thickness were the ones with the largest surface areas. (subjects 1 and 8) Fat thickness is difficult to measure with absolute reliability, expecially on the outer side of the thigh, and experimental error may account for the last two subjects showing lack of correlation, since it would be unreasonable not to expect weight to increase with fat thickness.

Considering each month individually, the correlation between weight (corrected for height) and mean fat thickness, was significant at the 1% level for all of the men. There was also a significant correlation at the 1% level between weight and fat thickness measured at sites 2, 3 and 5 in each month. There was no significant correlation between weight and fat thickness measured at site 4,(outer leg, one third way down thigh) suggesting that this is not a site at which fat is laid down during small changes in weight. The close correlation between fat thickness at other sites with weight, suggests that the increase in weight was not due to increased muscle mass but probably almost entirely due to deposition of fat and further, was probably of social origin.

The close positive correlation between body weight and skinfold thickness is in agreement with the results of Lewis et al (1960) and Davies (1969). Massey, (1956) worked with men in Antarctica over a period of two years. He found that during the first year the men showed a rapid shrinkage of fat thickness, but that during the second year there was a close relationship between weight and fat thickness.

Lewis et al (1960) found that the two sites of least value in predicting weight were the outer arm between deltoid insertion and elbow (site 1) and the outer leg, one third way down thigh. (site 4)

In our study, site 4 is not a good predictor of weight in any of the months, but site 1 is correlated with weight in six out of ten of the months analysed.

Analysis of Weight Records for Crossing

The following weights were the weights for four men for the period of the crossing. The readings for November were taken at Shackleton and the readings for December were taken at South Ice. The readings for January were taken at the South Pole and the readings for March were taken at Scott Base.

Weights in Kilograms

	Subject 10	Subject 8	Subject 12	Subject 9
November 1957	77.2	84.9	77.1	80.0
December 1957	74.5	86.8	78.2	80.2
January 1958	75.0	81.0	75.5	77.3
March 1958	73.6	77.0	76.3	78.2

Subject 10 is the only man whose weight increased from December to January, and this was not a significant increase. The weight of the other three men decreased from December to January.

Subject 10's weight decreased from January to March, and the weights of subjects 8, 9, and 12 increased for the same period. However, the weight of all the men decreased from November to March. It is doubtful whether much emphasis should be placed on these readings since the measurements were all made on different weighing scales under difficult conditions.

(5) SLEEP DATA.

The average number of hours of sleep were calculated for each man for the time spent at base. (Shackleton or South Ice) Base routine followed a fairly rigid pattern at Shackleton the year round, owing to the considerable noise made by the diesel generators which ran from breakfast time to lights out. Noisy work was impossible in the comparative silence after 11 p.m., and the sleep pattern averaged 7.4 hours.

There was no such rigid pattern imposed at South Ice by machine noise, and the men worked and slept as necessary. The sleep pattern became irregular and broken and will be dealt with seperately.

The Main Crossing Party from Shackleton to South Ice, (November 24th to December 23rd) the most difficult part of the journey, had an average of 6.8 hours sleep each twenty four hour period. From South Ice to the South Pole the two dog drivers averaged 7.3 hours a night while the vehicle party averaged 6.3 hours. (December 25th to January 19th) The hour less is due to the vehicle maintainance - dogs do a good deal of their own maintainance!

From the South Pole to Depot 700 the whole party moved together in vehicles over easier territory, the dogs having been flown out, and sleep averaged 6.0 hours a night, the reduction emphasising the long hours of driving necessary to cover the distance. It was late in the season and it was essential to make all speed to Scott Base. The last portion

of the journey from Depot 700 down to Scott Base again emphasised this pattern, sleep dropping to 5.1 hours a night. The men on arrival were nevertheless in good health and spirits, and although short by an average of an hour a night for over three months, only slept a few extra hours on arrival at Scott Base.

In general, the men who had the most sleep at base had the most on the crossing (subjects 5, 12, and 9) and those who had the least amount at base had the least amount on the crossing. (subjects 6 and 11) (Table IX (12))

Subject No.	Average Number of Hours of Sleep for Period at Base	Average Number of Hours of Sleep for Period of Crossing
1	7.5	6.3
2	7.3	6.2
3	7.2	6.0
4	7.5	6.2
5	8.2	7.1
6	7.0	5.9
7	6.8	6.4
8	7.2	6.4
9	7.6	7.2
10	7.5	6.4
11	6.7	6.0
12	7.7	7.0

Table IX (13) Average Total Number of Hours of Sleep for Twelve Men

X. D I S C U S S I O N O F R E S U L T S

(1) EVIDENCE OF ACCLIMATIZATION

The survey of literature in Section III has already drawn attention to the difficulty of deciding what can be taken as evidence significant of acclimatization to cold. The results presented here enable one to see whether or not less clothing was worn as time passed in closely similar climatic conditions, and the main assumption in this analysis is that if general body acclimatization occurs, then the individual will need less insulation to deal with the same cold stress.

The results show quite clearly that in this particular survey of this particular expedition, there is no evidence of less clothing being worn to meet the same cold stress as time passed, and this is true for both the period at base and during the crossing of the Antarctic Continent. In fact, the total amount of clothing worn increased when the temperature fell, and the corresponding removal of clothing that might be expected to occur when the temperature rose by a similar amount was consistently less than expected.

In fact, with the passage of time, the amount of clothing worn during the crossing increased slowly and steadily. This increase in the 'total number of layers' was mainly due to the increase in the number of layers worn on the upper trunk.

There is no doubt that the men experienced a considerable cold stress, especially during the crossing. (see Section IV) There was free access to their own spare clothing, and new clean clothing was available if needed to replace any soiled in a mishap while oiling or greasing a vehicle. There was no social or other barrier to wearing any particular combination or quantity of clothing. The increase in clothing was therefore not due to soiled clothing

becoming a less effective insulation layer, but the result of a voluntary decision to wear more.

This was also true of the period spent at base, although here the cold stress was less owing to the greater amount of time spent indoors, and the actual basic amount of clothing worn was less.

There was no similar increase with time in the clothing worn on the hands during the crossing. This is very likely to be due to the already well authenticated local acclimatization to cold that can take place in the hands. However, it may be significant here that the amount of clothing that can be worn on the hands is in fact ultimately limited by the resulting clumsiness.

These results are not in agreement with those of Goldsmith (1960) Palmai (1962) and Lugg(1965). This may well be because the conditions were much more severe than those considered by Palmai and by Lugg, but the conditions experienced by the Advance Party and analysed by Goldsmith were at least as severe as those during the crossing. Goldsmith only reported his figures as significant for hands, however, and the disparity is (probably) less than it appears.

This absence of evidence of acclimatization from clothing records may be linked with the likelihood already discussed that this group of men was already highly self selected, i.e. in choosing these conditions. In other words, the expedition members formed anything but a random population sample.

Several inadequacies must be born in mind when considering these results. Every new arrival quickly learns to adjust his clothing to suit changing conditions during the day. Both at base and on the crossing each man dressed for the day on first rising, judging what would be needed for the day from a quick glance outside, past experience, and a sharp memory of whether he was comfortable

the previous day or not. It is far too difficult to change clothing during the day (barring exceptional circumstances) and sweating must be avoided very carefully or the moisture will condense and freeze in the outer layers of clothing, thus lowering its insulation value greatly - even dangerously. While working hard the anorak hood is lowered, the draw strings loosened and movement then causes a flow of air through the anorak. When not exercising, heat is conserved by tucking the anorak into the windproof trouser waist band, and doing up the hood round the face. The tests at Farnborough showed that this simple manouvre decreased the clo value of the upper trunk clothing by about half a clo unit - a considerable amount - quite apart from the all important venting of moisture laden air and the heat loss due to evaporation. No record was kept of these simple and all important manouvres, but various combinations of these conditions can be seen in the numerous photographs taken during the expedition. It would not be feasible to keep a continuous record of these points, but they are obviously of importance. An automatic ventilation recorder would be helpful. However, all this is to avoid sweat wetting the clothing. Once the exercise is over, heat must again be conserved and this is the clothing record we are really concerned with i.e. that which is necessary for the man in normal activity, and under these conditions the hood is commonly up and the anorak tucked in or the waist draw string tightened.

Perhaps the most interesting point is that the new arrivals at Shackleton Base in January 1957 chose to wear the same amount of clothing as that being worn by the members of the Advance Party they were joining. No-one knew this at the time, and the facts only appeared when the data cards were analysed after the expedition was over. If the new arrivals were un-acclimatized, they might be expected to wear more clothing. If the members of the Advance Party had achieved acclimatization after their extremely harsh winter, they might be expected to wear less

than the new arrivals off the ship. The two groups in fact were practically identical.

A possibility is that the newcomers were already acclimatized before reaching Shackleton. They had entered the pack ice four weeks before, and reached Halley Bay two and a half weeks before the date of commencement of the detailed analysis considered here. They had then spent a week and a half at Halley Bay unloading stores and then proceeded to Shackleton Base. The full detailed analysis starts on January 20th 1957, (a week later) and the data cards of the Advance Party are considered in Goldsmith's analysis up to that date and in this analysis from that date onwards. The newcomers had been based on board ship all this time until moving ashore at Shackleton and it does not seem really likely that any serious degree of cold stress would be experienced until living ashore. All the meals were taken on board, men slept on board, and worked ashore - mostly driving vehicles unloading the ship during the warmest period of the Antarctic summer. The temperature averaged -6°C at Shackleton during this week. It is also possible that the members of the Advance Party had lost acclimatization to cold that they had acquired, owing to the rise in temperature after the winter. The fact remains that they both employed the same clothing insulation to deal with the same climatic conditions and there was therefore no difference between them in their state of acclimatization.

The difference in the clothing worn by one individual as distinct from another under any set of circumstances, could not be closely correlated with age, weight or fat thickness, or indeed any parameter tested, despite there being statistically significant differences between individuals. This was analysed closely only for the crossing data.

WIND CHILL AND TEMPERATURE

The concept of wind chill devised by Siple (from experiments on the cooling of naked containers of water) has been widely discussed and criticised, (Burton & Edholm 1955) but continues to be extensively used. In this survey the correlation between clothing worn and wind chill was much inferior to the correlation between clothing and temperature, and this was true for all the data, both at base and during the crossing. In other words, the clothing worn depended mainly on temperature, and this indicates that too much weighting is given to wind in Siple's wind chill device, for men wearing windproof clothing. The shelter given by buildings or by vehicles may also reduce the importance of wind enormously, and the temperature factor then would become the more important. At base, men dressed for the outside conditions, and there was no protection outdoors, but the correlation of clothing with temperature was still better than with wind chill. On the crossing the vehicle cabs, although cold, gave considerable protection from wind, although they had to be driven at times with windows or doors open. (Fuchs & Hillary 1958 a) Cab temperatures were as low as ambient temperatures on starting, but the temperature at head level rose above freezing point after an hour or so. The floor temperature was always well below freezing point, and was deliberately kept low to avoid any possibility of melted snow wetting the foot gear. Stops were frequent for various reasons, and cab temperatures dropped the instant a door was opened. When camping, the tent temperature rose above freezing point at sitting head level, while cooking, but commonly dropped to -10°C when the primus was out. Both cabs and tents did give protection from wind. The fact remains that the large amount of data analysed here indicates clearly a closer correlation between clothing worn and temperature than with clothing worn and wind chill, in a group of men experiencing very considerable cold stress over a long period of time.

(3) MULTIPLE REGRESSION ANALYSES

The multiple regression analyses also show clearly that temperature was the most important factor influencing both the 'total number of layers' of clothing and the number of layers on various sections of the body. This is at variance with Frazier,(1945) Butson, (1949) and Lugg (1965) who found that not much extra clothing was needed by the men at Little America III, Grahamland and Davis Base when the weather became colder. Goldsmith (1960) and Palmai (1962) both found that there were seasonal variations in clothing worn proportional to cold stress which is in accordance with the results presented here. Cloud cover was also significant in the multiple regression analyses for most of the men, especially for the upper trunk clothing, and this is believed to be due to the relation between cloud cover and incoming radiation, which is already known to be of direct importance.

In the multiple regression analyses of the factors possibly affecting the number of layers on the feet, temperature again emerged as the most important factor, but drift also appeared as a factor strongly influencing foot wear, as might be expected. Massey (1959) found that drift increased the numbing of fingers by between two and six times.

Altitude as a factor influencing clothing appeared to be of low importance, the regression coefficient being positive in some cases and negative in others.

(4) ACTIVITY AND CLOTHING

The apparent absence of a close relationship between the degree of activity and the clothing worn is puzzling at first sight, but, here again, the all important adjustment of the anorak hood and the waist line was not recorded and this would explain the observed facts.

We suggest that the men dressed according to the temperature and made frequent adjustments to the anorak to suit the wind and give sufficient ventilation to provide the necessary heat exchange. It is a matter of common observation that when an anorak is pulled out loosely at the waist, and the hood is down, then raising the arms up and down causes a pumping action readily providing ventilation of the upper trunk. This would adequately account for the absence of a close relationship between degrees of activity and clothing worn.

(5) CLO VALUES

The measurements of clo values showed that there is a simple direct relationship between the number of layers of clothing worn, and the clo value of the clothing assembly. If an absolute measurement of heat insulation is required then the tedious and difficult measurement of clo value must still be made at one of the few laboratories in the world that have the elaborate facilities necessary. For all ordinary purposes of relative comparison of good clothing used in cold climates, these investigations show clearly that a simple number of layers count is fully adequate. A very simple weighting of the count, giving the outer windproof layer (both trousers and anorak each) a value of two, and the long underpants a value of two if worn, gives the best correlation of all. The fact that these garments appear as the most important, indicates first of all the enormous importance of wind and windproofing, and secondly the difference between long underpants and vests. No weighting of the upper trunk underwear improved the correlations, indicating a real difference between vests and long underpants in their value as heat insulation. This is thought to be due to the long underpants being thick garments that clung tightly to the legs while the vests were loose and of different texture. It would be well worth experimenting with a vest of the same material and cut as that used for long underpants, for use in conditions of extreme cold stress.

The clo value of assembly '4' tested at Farnborough is of special interest as this was worn by subject number 10 during a forced landing from a small aircraft (Fuchs & Hillary 1958 b) The two occupants of the aircraft survived for eleven days on the ice shelf without a tent or a shovel, in temperatures between $-50^{\circ}C$ and $-60^{\circ}C$ on emergency rations of about 450 Kcalories a day by digging a hole in the snow and using just over one pint of paraffin in that time for cooking purposes. (the usual allowance of paraffin for winter sledging for two men is $1\frac{1}{2}$ pints a day) Neither was frost bitten, but sleep was in very short periods between bouts of violent shivering. The ice hole gave protection from the wind, but the subjects were not adequately insulated by the 3.1 clo units worn. Both lost weight and had marked ketosis as measured by Acetest tablets during the eleven days of exposure. Subject 10 drank $4\frac{1}{2}$ pints of fluid during the hour following arrival at Halley Bay and when weighed (nude) was then found to have lost 7lbs weight in the eleven days. This loss was presumably of fat, hence the ketosis.

There were differences between the clo value of assemblies measured at the Institute of Aviation Medicine at Farnborough and at the Wright-Patterson Air Force Base in U.S.A. of up to half a clo unit, the U.S.A. figures being higher. The differences are likely to be due to the difficulties experienced in putting the clothing on the Farnborough mannikin, and, despite unpicking and re-stiching seams, there was probably a tighter fit on the Farnborough mannikin with a lower clo value as a result.

(6) WEIGHT AND FAT THICKNESS

The seasonal fluctuation in weight recorded here is similar to that reported by Wilson (1960) and by Lewis, Masterton and Rosenbaum (1960), and probably indicates no more than a plentiful supply of food and a lower energy expenditure in the winter than in the summer. Davies (1969) found that the weight and fat thickness of the 1960-61 party stationed at Horseshoe Island and Stonington Island

Marguerite Bay, were not increased by exposure to low temperatures. The weight and skinfold thickness records of the Advance Party of the Trans-Antarctic Expedition also did not show seasonal changes. (Goldsmith 1959)

The loss of 3.4 Kg in the average weight of the ten men for whom figures are available for December 1957 and December 1958 is explained by the circumstances. The first figures were taken aboard the Magga Dan where exercise was limited. The second set were recorded (on different scales) at South Ice immediately after the heavy energy expenditure of crevasse probing during the most difficult and strenous portion of the crossing.

(7) SLEEP

The number of hours slept dropped from 7.4 a night at base to 6.8, then 6.3, then 6.0, then 5.1 hours during successive stages of the journey. This illustrated the pressure on the party to complete the journey in time to escape from Antarctica before the coming winter made return by ship to the outside world impossible. The overall lack of sleep and tiredness resulted in the men being able to sleep instantly and easily almost wherever there was an opportunity. It is normal to seek warmth and comfort when intending to sleep, and it is just possible that the steady increase in clothing recorded during the crossing is related not only to the low temperatures (as it obviously was) but to the increasing lack of sleep. No regression analysis has been done on this aspect since the concept only emerged when the work was being discussed. The analysis will be made later if possible.

(8) Acclimatization in the hands

The hands are the one region of the body in which acclimatization to cold has been clearly shown to occur by workers such as Mackworth (1953), Massey 1959, Le Blanc Hildes and Herous 1960 and Nelms and Soper (1962), and there is no doubt that it occurred in the members of the crossing party. A single example will suffice. For the last few days of the crossing a physiologist (Colonel J.M. Adam of the MRC, London) joined the crossing party and tented with the expedition's physiologist. The crossing party were finding the weather conditions warmer, having descended from over 2,000 m. altitude and temperatures of about -30°C, to the shelf ice just above sea level with temperatures of about -20°C. On breaking camp when the TAE member had been loading the sledge, as 'outside man' for about half an hour without gloves, he was joined by the 'inside man' with the last boxes. Despite wearing gloves both hands 'went off' and the inside man had to go back hurriedly into the tent to rewarm his hands, although he had already been several weeks in the Antarctic.

There is no direct evidence of acclimatization of the hands in these records, but it is worth noting that the increase in the number of layers worn on the hands was much less than the increases recorded over the rest of the body.

It was also noticed that the skin became slightly thicker and that fine sensation was a little dulled. Cracks appeared in the skin between the dermal ridges on the finger tips and some of these became deep and very painful. They all healed rapidly when the temperature rose, some healing before reaching Scott Base, and all within a few days of arrival.

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GLOSSARY OF SPECIAL TERMS

This is not a full glossary and only contains those terms of special importance.

AVERAGE	This always refers to the arithmetic mean.
BIT	The amount of information required to distinguish between 1 and 0 in the binary notation used in computers.
"GOING OFF"	A term commonly used to describe the painful initial stage of serious chilling of the hands. If neglected clinical frostbite may supervene.
INSIDE MAN and OUTSIDE MAN	When camping the 'Inside Man' prepares the food and does all the work inside the tent. The 'Outside Man' similarly looks after sledges, vehicles or dogs and so on.
P	Probability expressed as a number between 0 and 1. If the probability is 1, then it is a certainty. If the probability is 0.5, there is a 1:2 chance of the event occurring. If $p = 0.01$, then the probability of the event occurring is one in one hundred.
PROGRAM	Set of instructions for computer.
r	Sample correlation coefficient. It is the measure of the mutual relationship between two variables.
REGRESSION ANALYSIS	Estimation of one variable (the dependent variable) from one or more related variables, (the independent variable). The linear regression equation is written in the following form. $y = a_1x_1 + a_2x_2 + a_3x_3 + \ldots\ldots + b$ where y = dependent variable and $x_1, x_2 \ldots\ldots$ are independent variables.
SIGNIFICANCE	If for example an 0.05 level of significance is chosen in accepting or rejecting a test of hypothesis, then there are about 5 chances in 100 that the hypothesis would be rejected when it should be accepted.
THERMAL INSULATION	The thermal insulation of a body is the reciprocal of its thermal conductivity. Thermal conductivity is the heat flow in calories per second flowing across a centimetre cube with a temperature difference of $1^{\circ}C$ on opposite faces.

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University of Bristol,
Department of Physiology,
The Medical School,
Bristol BS8 1TD. U.K.

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A.F. Rogers and R.J. Sutherland.

ABSTRACT: A detailed computer analysis of the clothing worn by twelve members of the Trans-Antarctic Expedition, and weather records over fourteen months, including severe cold stress during the crossing showed no evidence of whole body acclimatization to cold in man. The clothing worn was more closely correlated with temperature than windchill. It is suggested man creates and controls his own micro-climate. A simple technique for comparison of thermal insulation of clothing assemblies is given.

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13. ABSTRACT

(1) A detailed computer analysis was made of the clothing worn by the members of the Trans-Antarctic Expedition, and the relevant climatic data. The analysis covers a period of just over fourteen months and includes the 2,158 mile journey across Antarctica. The cold stress was severe.

(2) No evidence of whole body acclimatization to cold in man could be found.

(3) The clothing worn was clearly shown to be more closely correlated with temperature than with windchill.

(4) The measured clo values of twentyeight different assemblies of Antarctic clothing were compared. A simple direct relationship between a weighted 'number of layers' count and the clo value of an assembly was shown to exist. This relationship is of immediate use in comparing the relative thermal insulation of two cold weather clothing assemblies.

(5) Other data, including weight fat thickness and sleep records, are discussed.

(6) The data presented are consistent with the suggestion that man creates and controls his own micro climate.

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14 KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
Antarctic Climate						
Antarctic Clothing						
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Sledging rations						
Windchill						
Thermal insulation						
Clo Value						
Body Weight						
Sleep records						
Fat Thickness						
Microclimate						
Trans-Antarctic Expedition						

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